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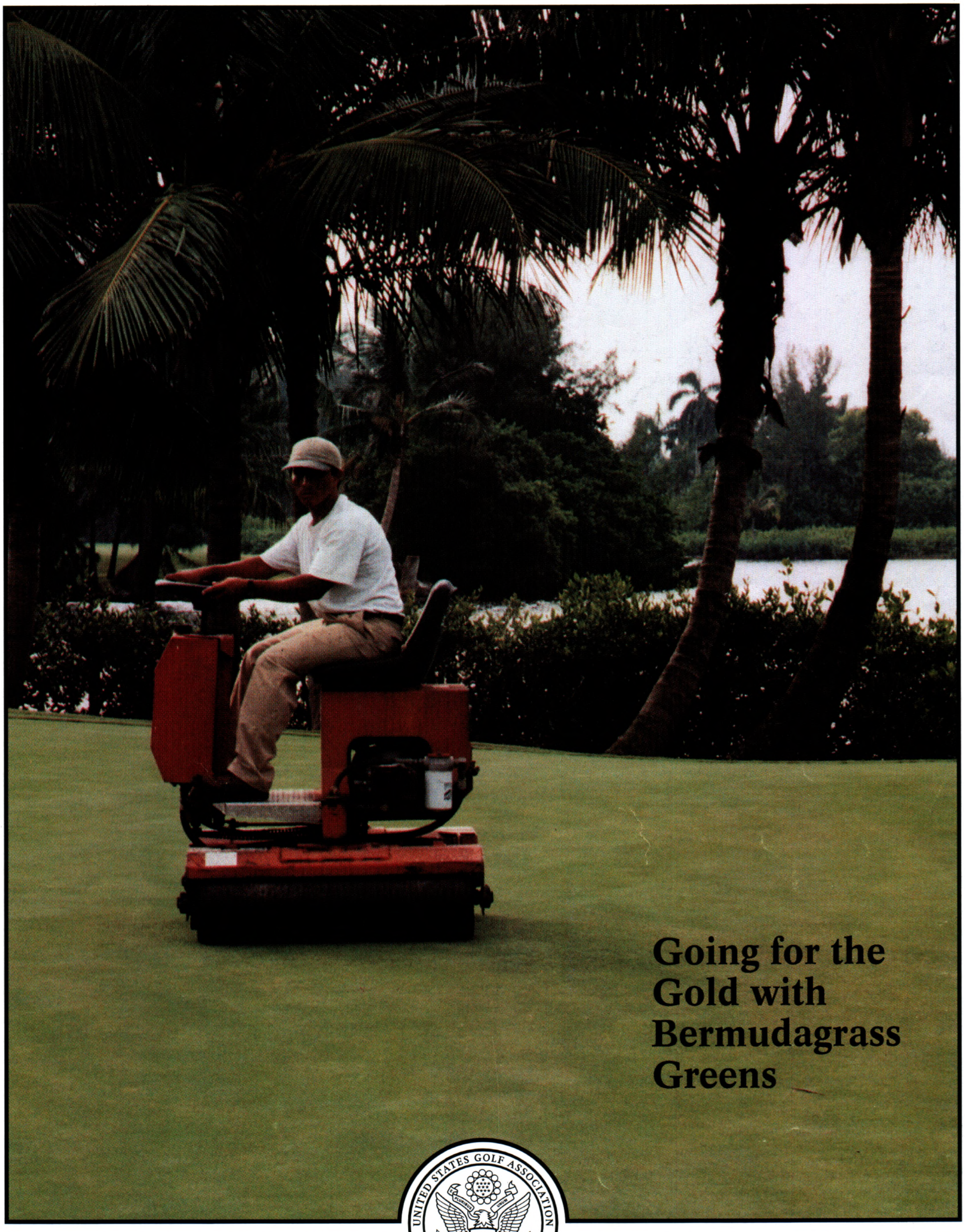

Going for the Gold with Bermudagrass Greens

A PUBLICATION ON TURFGRASS MANAGEMENT BY THE UNITED STATES GOLF ASSOCIATION®

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Cover Photo:
At courses where premium quality conditions are demanded, rolling and/or double cutting are now being conducted on a routine basis with bermudagrass greens.

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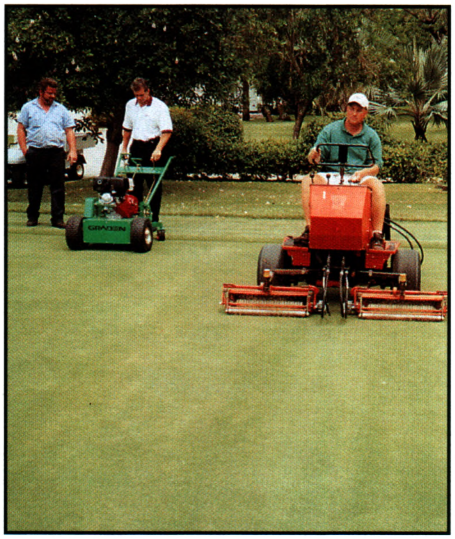
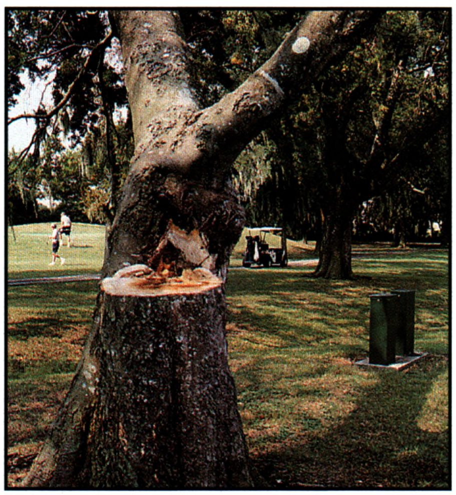


With only a few years of experience with the ultradwarfs, refining management practices such as verticutting is still underway. *See page 1.*



Unless manually removed, it is probable that this tree will fall and damage the irrigation controllers below. *See page 13.*

Going for the Gold with Bermudagrass Greens: Part II

While the basics remain the same, tools have become available to help "fine-tune" the conditioning of bermudagrass putting surfaces.

by JOHN H. FOY

A faster rate of organic matter accumulation is a concern with the ultradwarfs. If not properly managed starting at establishment, a problem can quickly develop. The accumulation in this photo developed in a little over six months.

GOING FOR THE GOLD with bermudagrass greens is certainly achievable today. Over the past several years, further refinements in management programs and new techniques such as growth regulator treatments have become available[1] These updated management strategies have made it possible to provide a level of quality more in keeping with current demands and expectations. With proper resources and good management, outstanding playing surfaces for regular and championship play can be provided with bermudagrass greens.

New bermudagrass cultivars called "ultradwarfs" are also available now. These new bermudagrasses are further raising the standards of putting green quality on golf courses throughout the hot, humid regions of the country.

Updated Management Strategies for Bermudagrass Greens

Spoon feeding fertilization: Relative to other turfgrasses, the bermudagrasses have a higher fertilization requirement to produce and maintain a dense, green turf cover. The rule of thumb with Tifdwarf and Tifgreen putting surfaces has been to supply 1 lb. of actual nitrogen per 1,000 sq. ft. per month during the growing season. While not fully supported by university research, the practice of nitrogen to potassium fertilization ratios in the 1:1 to even 1:2 range has also been found to produce the best results at most courses. To supply this amount of nutrients, applications of granular fertilizers on a schedule of every 2 to 4 weeks has been the standard regime for many years. Yet at times, difficulties have been encountered in trying to maintain a constant shoot growth rate and consistent playability.

Spoon feeding, generally consisting of spray applications of low rates of readily available nutrients on a frequent basis, has been a common practice with cool-season turfgrass putting greens for many years. With bermudagrass putting greens in Florida, it took the persistence of an abnormal and adverse weather pattern to produce a change in fertilization practices. With the onset of the El Niño weather pattern and a prolonged period of excessive rain, it was difficult to follow standard fertilization programs. Besides not being able to apply and water-in granular fertilizer materials, fertigation was not an option either because supplemental irrigation

At a growing number of courses around the state of Florida, conversion to one of the new ultradwarf bermuda cultivars has or will be made in the next few years.

was not needed. Thus, out of sheer desperation, spray application fertilization programs were undertaken at courses around Florida. It was quickly realized that spoon-feeding was a viable strategy for maintaining bermudagrass greens.

Along with being able to manage shoot growth rates more effectively, another positive aspect of spoon-feeding is that total annual fertilization rates have been reduced. At a few courses, spoon-feeding programs are being practiced exclusive of all other methods. However, some concerns do exist about being able to supply and maintain adequate nutrient availability with this approach and in turn sustaining uniform growth. A more common and, in my opinion, safer strategy is to maintain a nutrient base with once-a-month applications of a complete type granular fertilizer that contains a slow-release nitrogen source. It is suggested to supply 0.5 lbs. of actual nitrogen per 1,000 sq. ft. with each application. Then, in between and on an every-5-to-10-days schedule, spoon feed 0.1 to 0.25 lbs. of nitrogen per 1,000 sq. ft. per application. Regular soil and tissue nutrient testing should be performed to ensure that adequate and balanced nutrition levels are maintained.

Double cutting and rolling: With Tifdwarf, and even more so with Tifgreen putting greens, there are times when an elevated height of cut must be maintained to ensure turf survival. In Florida during the summer rainy season, sunlight intensity is reduced due to the persistence of overcast skies. The bermudagrasses have a high sunlight requirement, and just a few days of heavily overcast weather can negatively impact health and quality. If a height of cut of 5⁄32" or less is being maintained, turf density and health begin to decline and rapid invasion of algae can be expected. Double cutting and/or rolling are practices that can compensate for a higher height of cut and continue to provide a smooth ball roll and medium to fast putting speed.

In the past, double cutting and/or rolling of putting surfaces were practices that were reserved for tournaments or special events. However, in an effort to accommodate golfer demands for fast to very fast putting speeds, these practices are being conducted on a routine basis at more and more courses. At one club in Naples, Florida, double cutting the greens is typically performed more than 200 days a year. Obviously, this consumes a significant number of additional manpower hours and reduces the life expectancy of the mowing units. More time also is required to complete course preparations each morning. The members, however, are very supportive and accept the additional cost incurred because they are provided with top quality putting green conditioning.

During the early to mid-1990s, rolling of putting surfaces increased in popularity. In addition to increasing putting speeds, this practice produces a marked improvement in surface smoothness with bermudagrass greens. A concern with rolling putting greens, however, was the increase of soil compaction and its effect on turf health over the long term. In a study conducted at North Carolina State University, it was found that no change in compaction occurred with high-sand-content USGA-type rootzone mixes, even when daily rolling was conducted for 70 consecutive days.[2]

It has been my experience that the best results are achieved when bermudagrass greens are rolled two to four times per week. Care does need to be exercised when the turf is not actively growing or is under stress because of the excessive wear that can occur around the perimeters of the putting surfaces.

Topdressing: Sand topdressing of putting surfaces is a basic management practice that goes back to the links courses of Scotland. Along with having an important role in rootzone management, topdressing produces a smoother, more consistent surface and faster putting speeds. In applying topdressing, the rule of thumb is to try to match the frequency and amount of material with the growth rate of the turf. During the summertime, when active bermudagrass growth is occurring, topdressing every two to four weeks has been the standard regime used at most courses. However, because of equipment limitations it was difficult to accomplish light applications in a timely and efficient manner. Along with inconveniencing golfers, a few days were required for the sand to work down into the turf canopy and for a good playing surface to redevelop.

Improvements in application equipment have been made so that very light dustings of sand can be made and all the greens topdressed in a few hours. With these light applications, brushing or even overhead irrigation can be performed to work the sand down into the turf so that most golfers can't tell that a topdressing has been performed. Furthermore, the use of dry material facilitates application and incorporation into the turf. At the courses where premium quality conditioning is being maintained, the putting surfaces are dusted on a 5-to-10-day schedule. With more frequent topdressing, however, extra attention must be given to maintenance of the mowing units to keep them in precise operating condition.

Growth regulator treatments: Uniform turf growth is needed to ensure the persistence of good coverage and recovery from traffic and wear damage. Excessive shoot growth rates, however, negatively affect playability and, in particular, reduce putting speeds. Thatch accumulation also is a concern with high growth rates. As mentioned earlier, spoon feeding fertilization programs can help manage the growth rate of bermuda putting surfaces. However, during the summer months, difficulties with rapid growth and inconsistent conditioning can occur. Especially during the mid to late afternoon, a noticeable decline in putting speeds can be a problem. Conducting a second midday mowing of putting greens is not an option, nor is it a practical solution at most courses.

In the early 1990s, the turfgrass growth regulator trinexapac-ethyl (Primo) rapidly gained popularity as a management tool for bermudagrass fairways and tee surfaces. Monthly treatments slowed down shoot growth rates, mowing frequency was reduced, and there were less turf scalping and clipping accumulation problems. Additional benefits of the trinexapac-ethyl treatment program are increased density and a darker green color with reduced fertilization. The use of a growth regulator on bermudagrass fairways has become widely accepted and is now a standard practice at courses throughout Florida.

When discussions about using a growth regulator on bermudagrass putting surfaces first started, I had a number of reservations about this practice. However, testing of low-rate applications was undertaken and it was found that more consistent and faster putting speeds could be maintained at the same or even a slightly higher height of cut. A "dwarfing" effect also occurs, such that turf density is increased. Trinexapac-ethyl treatments also help mask off-type surface contamination. In 1996, a label revision was made that allows use of this growth regulator on Tifdwarf and Tifgreen greens.[3] As with fairways, treatment of bermuda putting surfaces with growth regulators has become a widely accepted practice. At the vast majority of courses in Florida, treatments are being conducted on a regular basis throughout the growing season and no adverse side effects have been noted. The ability to effectively manage growth has had a significant positive impact on being able to produce and maintain consistent conditioning of bermudagrass putting surfaces.

Experiences with the Ultradwarf Bermudagrass Cultivars

There is simply no way around the fact that over the past 10 to 15 years, golfer expectations and demands have risen dramatically. Even with the knowledge and management tools available today, meeting these demands with Tifgreen bermudagrass greens is an almost impossible challenge. Tifdwarf is also being pushed to its limits. Furthermore, while a degree of success has been achieved in maintaining bentgrass putting greens in hot, humid regions, it is not an environmentally and economically sound approach. Thus, there is lots of interest in new bermudagrass cultivars that have improved performance characteristics and are better adapted for meeting current demands.

Since the 1980s and continuing through the 1990s, efforts have been underway by turfgrass breeders, producers, and golf course superintendents to develop or select improved bermudagrasses for putting greens. This resulted in the introduction of new cultivars that are now being commonly referred to as *ultradwarfs.* While there are genetic and morphological differences between the cultivars, all the ultradwarfs have a higher shoot density and finer leaf blade relative to Tifdwarf. They also have exhibited excellent tolerance to a $\frac{1}{8}$" height of cut for extended periods of time. At a few courses, heights of cut of $\frac{1}{10}$" or even less are being maintained. The improved performance characteristics of the ultradwarfs make it possible to provide an extremely smooth ball roll and, when desired, fast to very fast putting speeds. Although additional time is needed for thorough evaluation of these new cultivars, generally it is agreed that one or more of them will replace Tifdwarf as the standard on putting greens in hot, humid regions.

Champion, FloraDwarf, and TifEagle are the commercially available ultradwarfs, and the cultivar MiniVerde was released recently. In 1997, the first full set of ultradwarf (Champion) putting greens was established in Florida on the Cypress Course at Bonita Bay East in Bonita Springs. Since then, ultradwarfs have been used for replanting or on new greens at nearly 100 courses around the state. No doubt this number will increase rapidly over the next few years, given the number of courses where replanting is needed to address surface contamination problems and with new construction continuing at a fast pace.

Check the temperature of bermudagrass sprigs. If excessive temperatures build up in shipment, sprig viability and turf establishment will be affected.

Concerning management of ultradwarf putting surfaces, they still are all bermudagrasses and, as such, a lot of the basics are similar to what is required to produce and maintain premium quality conditioning with Tifdwarf. Yet, there are also some differences that have been identified. The following is a summary of experiences with managing ultradwarf greens at several courses around Florida over the past two to three years.

Planting and establishment: The hybrid bermudas do not produce viable seed and thus must be established via vegetative means. Sprigging has been and continues to be the standard planting process.[4] While there is some debate over the exact size of a bushel, sprigging rates in the range of 20-30 bushels per 1,000 sq. ft. typically have been used with the ultradwarfs. At a few courses, however, it was observed that the establishment of full turf coverage was slowed down significantly with a low sprigging rate. It is being recommended with TifEagle that sufficient material be uniformly spread over the soil surface so that there are no open voids greater than 3". This is a good guideline since sprigging rates can be subjective, and after being mechanically cut in, it is very difficult to gauge the actual amount of material used. Full turf coverage can be established in as little as six to eight weeks with the ultradwarfs.

A major difference that has been noted with the grow-in of ultradwarf greens is the need to start mowing at a significantly lower height of cut. As with Tifdwarf, mowing the greens is initiated 10 to 14 days after sprigging. However, instead of starting out at about ⅜", the mowers need to be set up in the range of 5/32" to 3/16". Then the height of cut needs to be lowered progressively to ⅛" and maintained at this height through the grow-in process. For quite a few people, this has taken some getting used to. Furthermore, the ultradwarfs need and respond to frequent verticutting, spiking, and topdressing during grow-in.

Thatch/biomass management: A concern that was identified early on with the ultradwarfs was their faster rate of thatch/biomass accumulation relative to Tifdwarf. While there is some debate over terminology, it is still a fact that the ultradwarfs can produce a distinct and significant organic mat layer between the turf surface and rootzone mix. The bottom line is that this is an important management consideration, and from the start, programs need to be geared to not allowing an excessive organic matter accumulation to develop. Prevention is the key to ensuring long-term successful results with the ultradwarfs.

Based on experiences at a number of courses and on university research, nitrogen fertilization has a very important role in the management of thatch/biomass accumulation and turf quality.[5] While certainly not a new concept in turfgrass and putting green management, it has taken a little bit of time to determine the best programs for maintaining good turf quality without causing excessive growth and organic matter accumulation. At this time, a program of supplying 0.5 to 1.0 lb. of actual nitrogen per 1,000 sq. ft. per month during the growing season is suggested. The frequency of applications is as important as the amount of nitrogen being supplied. Spoon feeding programs are the standard approach being used at the vast majority of courses with ultradwarf putting surfaces. While granular fertilizer applications also are being made, the very dense turf cover of the ultradwarfs can cause problems with getting the materials down into the canopy. This is true even with mini- or micro-blend formulations. As far as the other macro- and micronutrients are concerned, ultradwarf requirements appear to be fairly consistent with those of Tifdwarf. An increased incidence of leaf spot disease activity has been observed on TifEagle putting surfaces when adequate potassium levels are not maintained.

Along with careful nitrogen fertilization, frequent and light verticutting/grooming and topdressing are needed with the ultradwarfs to maintain optimum turf quality and prevent excessive organic matter accumulation. During the growing season, these practices need to be conducted on a weekly basis. Unlike Tifdwarf, severe verticutting or excessive topdressing rates can be very detrimental to the ultradwarfs. As with granular fertilizer applications, some difficulties have also been encountered with incorporation of topdressing sand due to the very dense canopy of the ultradwarfs. Light verticutting or use of groomer attachments to open up the turf canopy prior to topdressing is a common and successful strategy being used at a number of courses. Another option that is gaining popularity is using rotary fertilizer spreaders to apply dried and bagged topdressing sand. This approach allows very light applications in an efficient and timely manner.

With astute fertilization and adherence to good topdressing and verticutting regimes, thatch/biomass accumulation with the ultradwarfs can be managed effectively. Thus, additional coring, relative to what is routinely done with Tifdwarf putting surfaces, has not been required. In the Central and South Florida areas, three coring operations during the growing season with ½" diameter or larger tines has been adequate for management of rootzone physical characteristics. As with Tifdwarf greens, however, care does need to be exercised during late summer and early fall with mechanical operations. During this time, intense environmental stress also occurs and recovery from damage is delayed. Furthermore, as with Tifdwarf greens, periodic water injection cultivation (WIC) or small-diameter aerification is very beneficial and encouraged.

Other considerations: In this article it will not be possible to cover in detail every aspect of managing ultradwarf bermudagrass putting surfaces. In fact, we are still in the learning process with these new cultivars. There are a few other management factors to consider, though.

First, it is well established that bermudagrass has very poor shade tolerance. Early on with the ultradwarfs, it was speculated that their increased shoot density and finer leaf blade would provide a degree of shade tolerance. This has turned out not to be the case. At several courses that have converted to one of the ultradwarfs, problems have been experienced with maintaining a dense, good quality turf in all the same areas where shade was a problem before. Full sunlight exposure, all day long, is an absolutely essential ingredient in maintaining top quality bermudagrass putting surfaces. This is true regardless of the cultivar. Furthermore, the ultradwarfs also are negatively impacted when sunlight intensity is reduced by heavy overcast conditions. Maintaining a slightly higher height of cut during the rainy season is advisable, but on the positive side, it is still possible to provide a good quality playing surface.

Next, the ultradwarf cultivars Champion, MiniVerde, and TifEagle all possess improved cool-temperature color retention and growth relative to Tifdwarf. Thus, for courses in South and even Central Florida, the need for winter overseeding is further reduced.

When cold nighttime temperatures do occur, some loss of green color results. However, with the return of milder temperatures, it is possible to produce a rapid greenup response. By not having to overseed, golfers do not have to put up with the disruptions and inconvenience of the fall establishment and spring transition operations.

For North Florida and the Southeast, a period of winter dormancy will still occur, and at facilities where moderate to heavy play is hosted during this time, interseeding/overseeding programs will still be necessary. The increased density of the ultradwarfs has been perceived as an obstacle to overseeding establishment, but successful results have been achieved at a number of courses. It also should be pointed out that at a couple of courses, satisfactory results have been experienced by not overseeding, but covering the putting surfaces during times when freezing temperatures are expected.

Finally, an additional attribute that has been noted with the ultradwarfs is increased resistance to fairway/rough bermuda encroachment. Encroachment of coarse-textured bermudagrass into the perimeters of Tifgreen and Tifdwarf putting surfaces is an age-old problem that results in a progressive loss of usable surface area. With the combination of increased density and being maintained at lower heights of cut, at least so far, encroachment problems have not been experienced on ultradwarf greens.

As to the life expectancy of ultradwarf putting surfaces, only time will tell. Yet, it is reasonable to expect them to at least be equal to the 10- to 20-year life of Tifdwarf putting surfaces. With more control and emphasis being placed on production quality control and turfgrass certification, we hope it will also be possible to avoid or reduce the contamination problems that have plagued bermudagrass courses in the past.


More frequent light topdressing is another means of providing a smooth, true ball roll and medium to fast putting speeds.

Summary

Maintaining extremely fast putting speeds at all courses with bermudagrass greens is not being encouraged or condoned. Yet, the standards of conditioning and quality have been raised and the benchmark continues to be set by bentgrass greens. For southern golf courses with bermudagrass greens, providing comparable conditioning has always been a challenge. With the knowledge and tools available today, however, it is possible to maintain a smooth, true ball roll and a consistent putting speed throughout the course. As discussed in this article, there are practices that can be used to produce faster putting speeds if there is a commitment to providing the necessary resources.

Furthermore, while it is still early in the game, the new ultradwarf bermudas are providing a more level playing field for southern golf courses. At the courses where they have been used, the golfers have been pleased with the improved playing surfaces. It should be stressed that the ultradwarfs do require intensive management and thus may not be suited for all courses. There is still not a perfect grass, but at courses where premium quality putting green conditioning is expected or demanded, the ultradwarf bermudas are an option that merits strong consideration.

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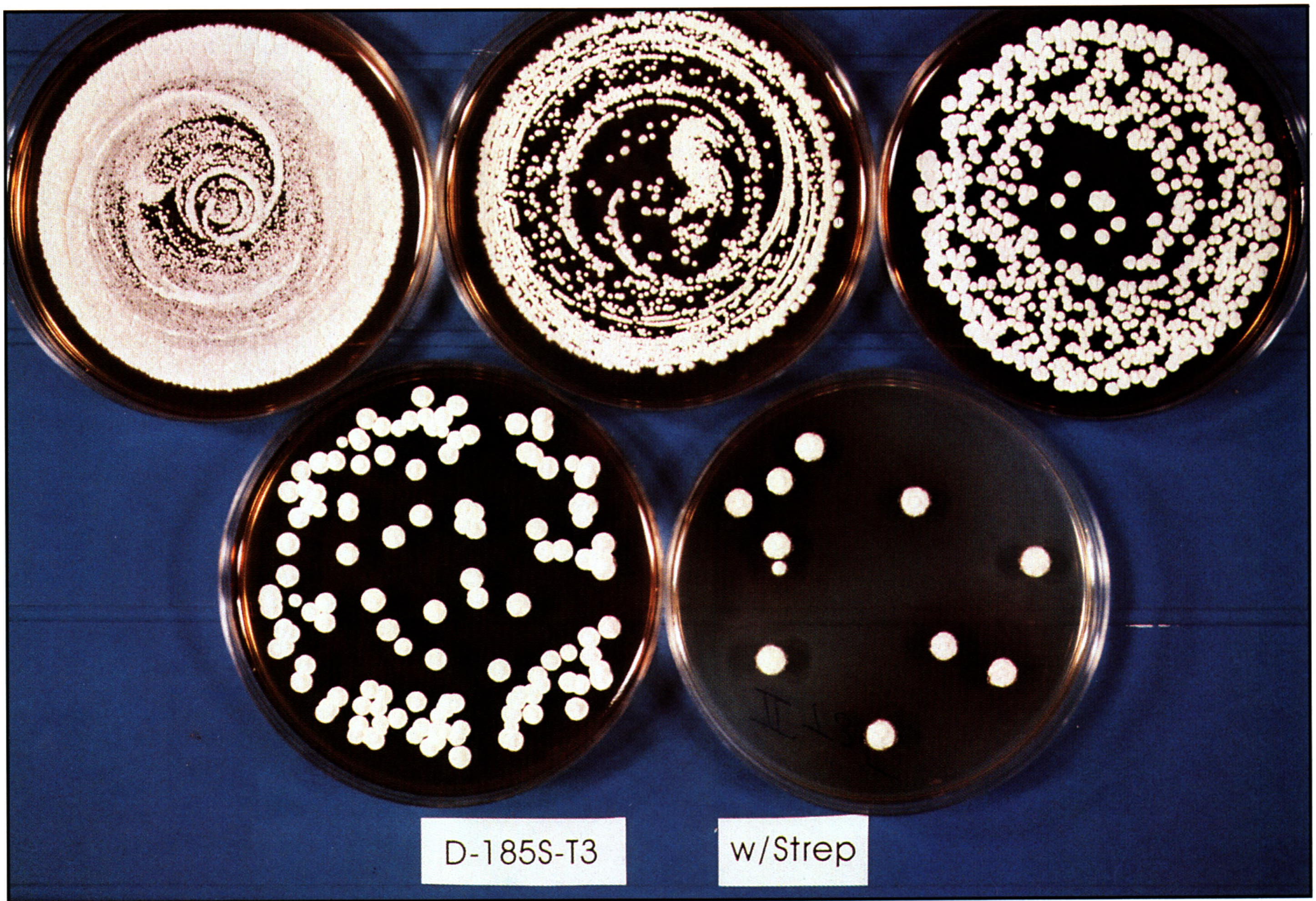


In counting millions of bacteria from the soil, microbiologists use a technique called "dilution plating." A soil or root sample is mixed in a liquid and then diluted to a point that will allow the bacteria to grow as distinct colonies on selective or non-selective media.

BLACK BOX RESEARCH

Seeking answers to the effectiveness of bacterial inoculents.

by MONICA L. ELLIOTT, Ph.D.

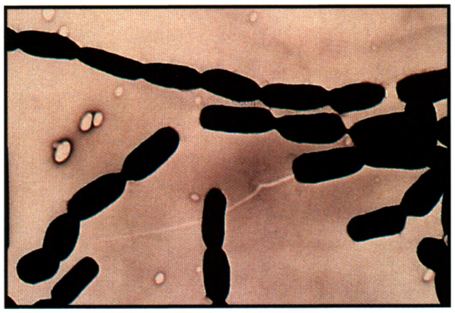
THE PLANT rootzone, often referred to as the rhizosphere, is truly a black box of the microbial unknown (Bowen and Rovira, 1991). While extensive research has been conducted on the roots of annual crops such as corn, wheat, and cotton (Pankhurst et al., 1996), research on turfgrass roots and the soils or rootzone mixes they inhabit has only just begun. When so few facts are known, myths are bound to develop. A common myth is that golf course soils, especially putting greens, are sterile environments with few microbes. We have already learned that is not true (Mancino et al., 1993; Liu et al., 1995; Elliott and Des Jardin, 1999a). What we want to learn now, if possible, is how to manipulate microbial populations in the rootzone.

Terminology

First, definitions of commonly used terms are in order. *Microbes* refers to bacteria and fungi. In this article, only bacteria will be discussed. *Bacteria* normally are single-cell organisms whose genetic material is not separated from the rest of the cell by a membrane. In contrast, fungi and plant cells do have their genetic material (nucleus) separated by a membrane. *Colony forming units* (CFU) is the measurement used to describe bacterial populations. In theory, each colony on a plate represents a single cell. Because bacterial numbers are so large, they are converted to log values. Instead of stating there are 2,700,000 CFU, we state there are $\log_{10}6.4$ CFU.

Common bacterial groups referred to in this article are: 1) fluorscent pseudomonads that glow in the dark with a UV light, 2) gram-negative bacteria, 3) gram-positive bacteria, 4) heat-tolerant bacteria that survive a 10-minute soak in a 176°F water bath, and 5) actinomycetes that look like fungi. Gram reactions (positive or negative) refer to a simple test that differentiates bacteria, based primarily on their cell wall components. Most heat-tolerant bacteria produce a specialized cell called an endospore. Actinomycetes also produce spores, but they are not tolerant of extreme heat. They are often confused with fungi, but they are not related. The five groups listed above are detected using selective media.

A sixth group of bacteria is referred to as *total aerobic* bacteria. They represent all the bacteria that will grow on a non-selective medium. The counts for the other groups will *not* add up to the count for the "total" group. It is critical to understand that this technique of growing bacteria on media only accounts for approximately 10% of the bacteria in the soil (Olsen and Bakken, 1987). We have not learned how to grow most bacteria in the laboratory. This is just one of many techniques for examining bacterial populations. We use this technique because we want to save many of the bacteria we isolate for future research.



A highly magnified look at actinomycete spores. They may look like fungi, but they are bacteria. This group is the source of most antibiotics.

Background Research

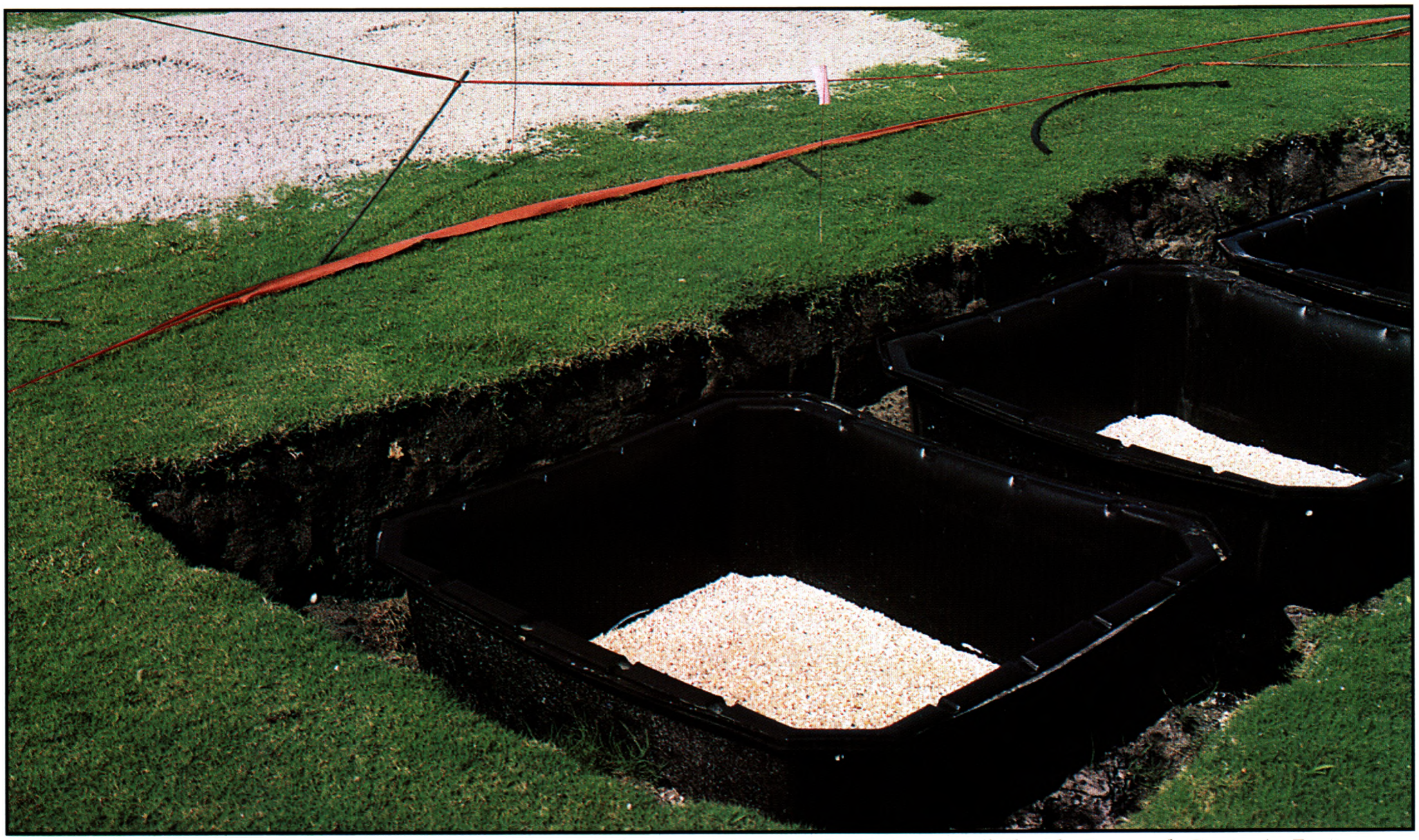
In a previous study we examined the effects of four natural organic nitrogen fertilizers on bacterial populations of an established (four years old) bermudagrass putting green (Elliott and Des Jardin, 1999a). For two years these products, plus a synthetic organic fertilizer, were applied to the putting green every two weeks at the normal South Florida annual rate of 18 pounds N per 1,000 square feet. Significant differences in bacterial populations due to fertilizer treatments were not observed. In other words, bacterial populations remained the same despite using natural organic fertilizers, even the two fertilizers that had bacteria added to them. There also were no consistent differences observed among the fertilizer treatments on turfgrass growth or quality (Elliott and Prevatte, 1997).

Every scientist wants to obtain dramatic, eureka!-type results, but we did not. Why? Two reasons may explain our results. First, since the putting green was maintained as a regular green, it was topdressed routinely (every two weeks). The topdressing (80/20 mix) did contain bacteria; in fact, more than the fertilizers. Second, since this was an established green, perhaps an optimum level of bacteria had already been obtained.

New Research

For the next project, research started at the beginning — the very beginning of putting green construction. Questions to be considered were: Do brand-new greens have different bacterial populations? Would peat sources affect bacteria? Does fumigation kill all the bacteria in the rootzone mix? What bacteria rebound first after fumigation? What bacteria are associated with the bermudagrass sprigs?

At the research center, trenches were dug for placement of 100-gallon Lerio™ tree containers, 36 inches square and 18 inches deep, to build mini-greens. A 6-inch layer of non-calcareous, washed river gravel was placed in the bottom of each container. No intermediate layer was added, as the gravel and the two rootzone mixes evaluated complied with USGA recommendations. The rootzone mixes, matched for physical characteristics, contained either Canadian sphagnum peat (85/15 mix) or Dakota reed sedge peat (93/7 mix). The subplot or second



Mini-greens were constructed in 36-inch square, 18-inch deep containers at the University of Florida Research Center in Fort Lauderdale. Soil and turfgrass samples were taken throughout the experiment to determine population sizes of six bacterial groups.

Table 1
Bacterial populations associated with individual components of the rootzone mixes and the bermudagrass sprigs planted into the mixes.

	log^{10} colony forming unit of bacteria*					
	Fluorescent pseudomonads	Gram-positive	Gram-negative	Actinomycetes	Heat-tolerant	Total
Sand alone	0	2.4	3.4	2.7	2.7	5.0
Sphagnum peat alone	0	1.2	5.8	2.3	4.1	6.6
Reed sedge peat alone	3.7	4.2	6.4	7.5	7.1	8.4
Sand/sphagnum peat rootzone mix	1.6	0.5	4.5	0	3.0	5.8
Sand/reed sedge peat rootzone mix	1.3	0	4.5	0	5.2	6.3
Bermudagrass sprigs	4.5	4.1	7.1	5.6	5.5	8.0

*Values are based on gram dry weight of either each component, rootzone mix, or plant material

factor in the experiment was fumigation type. The containers were either not fumigated (control) or were fumigated with methyl bromide (1 pound per cubic yard, injected) or metam sodium (2 gallons Metam 326 per 1,000 square feet).

Soil and/or turfgrass samples were obtained to determine population sizes of the six different bacterial groups for the individual rootzone components prior to blending and each rootzone mix after blending, but before placement in containers. Samples also were obtained from each container just prior to fumigation, 10 days after fumigation, 25 days after fumigation, and each month after planting of bermudagrass for five months. Samples also were obtained of the bermudagrass sprigs prior to planting. Protocol for the experiment was based on previous bermudagrass research (Elliott and Des Jardin, 1999b).

Bacterial populations associated with individual mix components, final mixes, and bermudagrass sprigs are presented in Table 1. The sand and sphagnum peat contained the lowest number of bacteria, with one group not detected at all (fluorescent pseudomonads). All bacterial groups were detected in the reed sedge peat. They were also all detected on the grass. This is important to remember since bermudagrass is vegetatively propagated and not seed propagated.

When the containers were sampled just prior to fumigation, there were

Table 2
Effect of fumigation on bacterial populations in putting green rootzone mixes. Since significant differences were due to fumigations, results from the two mixes were combined for analysis.

	log^{10} colony forming units of bacteria per gram dry weight of soil*					
	Fluorescent pseudomonads	Gram-positive	Gram-negative	Actinomycetes	Heat-tolerant	Total
Pre-fumigation	2.2	2.4	4.9	4.4	4.1	6.8
10 days after fumigation						
Control (no fumigation)	1.0^{D}	2.3	4.7	3.8	4.1	6.3^{D}
Metam Sodium	0.9^{D}	1.4^{D}	3.1^{D}	2.5^{D}	4.5	5.9^{D}
Methyl Bromide	0.1^{D}	5.0^{I}	5.5	2.6^{D}	5.2^{I}	7.0
25 days after fumigation						
Control (no fumigation)	1.3^{D}	1.1^{D}	4.4	3.9	4.1	6.0^{D}
Metam Sodium	4.0^{I}	1.2^{D}	5.3	3.4	5.7^{I}	6.8
Methyl Bromide	0^{D}	4.9^{I}	5.2	3.0^{D}	5.2^{I}	7.0
50 days after fumigation						
Control (no fumigation)	4.7^{I}	2.4	5.5^{I}	4.8	4.5	6.5
Metam Sodium	4.9^{I}	3.0	5.6^{I}	3.9	5.6^{I}	6.7
Methyl Bromide	4.4^{I}	4.6^{I}	5.6^{I}	4.4	4.8^{I}	6.9

*Values followed by a ^{D} are a significant decrease ($P = 0.05$) from the pre-fumigation values. Values followed by an ^{I} are a significant increase over the pre-fumigation values. If values have no ^{D} or ^{I}, then they are not significantly different from the pre-fumigation values. Statistical comparison conducted using Dunnett's t-test, $P = 0.05$.

greater numbers of Gram-negative bacteria and total bacteria in the sand/sphagnum peat mix than in the sand/reed sedge peat mix. The actinomycetes and heat-tolerant bacteria were greatest in the reed sedge peat mix. After fumigation, there was no overall significant difference between rootzone mixes. Significant differences observed in bacterial populations were due to the fumigation method (Table 2). Ten days after fumigation, the least number of each bacterial population was often associated with the metam sodium fumigant. At 25 days after fumigation, the most interesting observation was that the fluorescent pseudomonads were no longer detected in any of the containers fumigated with methyl bromide. Although the bermudagrass had been planted for one month at 50 days after fumigation, the containers were less than 50% grown-in. Therefore, we conducted a third post-fumigation sampling of just the soil. By this time, all the bacterial populations had rebounded and were either equal to or greater than the pre-fumigation populations.

When the results from the four monthly post-planting turfgrass samples were evaluated, there were no significant differences due to type of rootzone mix or fumigation method. Differences were due to the month the samples were obtained. The highest counts were for four and five months post-plant, whereas the lowest counts were for two and three months post-plant (Table 3).

Conclusions

As we have demonstrated, *bermudagrass putting greens are not devoid of bacteria.* Even newly constructed greens rapidly build up bacterial populations that include the most common groups associated with soils.

While the goal of research projects is to answer questions, new questions will also be raised. One concerns the application of general bacterial inoculants on the golf course. Some products claim to include 20 or more different bacteria. Because these products are not regulated and usually not evaluated, it is difficult to know what the consumer has actually purchased. If a product's only claim is to increase bacterial populations in the soil, this is probably a questionable benefit. Even if a product has proven to be effective on bentgrass, it does not mean it will be effective on bermudagrass. Also, some products contain more than just microbes. Often, nutrients or plant hormones are part of the formulation also.

The superintendent's best research tool for determining if a product will benefit a course is a piece of plywood. Simply place the plywood in the center of the green before applying the microbial inoculant product. Evaluate this control plot in comparison to the area treated with the product. Alternatively, apply the product to only one half of each green. Unwilling to take these chances? Then why are you taking a chance with the product in the first place?

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Table 3
Comparison of bacterial groups found on bermudagrass roots at two to five months after the bermudagrass was planted.

	log10 colony forming units of bacteria per gram dry weight of roots*					
	Fluorescent pseudomonads	Gram-positive	Gram-negative	Actinomycetes	Heat-tolerant	Total
2 months post-plant	5.2c	4.4b	6.9b	6.5a	5.9c	8.0c
3 months post-plant	5.8b	3.8c	7.2a	6.4a	6.1b	8.2b
4 months post-plant	6.1a	5.9a	7.2a	6.4a	6.3a	8.4a
5 months post-plant	5.9b	6.2a	7.0ab	6.4a	6.3a	8.2ab

*Values in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan *k*-ratio *t* test.

Temporary Sanity

A year-round approach to maintain your aprons as they need to be — firm and dry!

by LARRY GILHULY

SCENE 1: It is midsummer at the golf course and you are facing a shot into the wind with a hole location close to the front edge on the first hole. The greens have been very firm all week; the only shot is the favored bump-and-run off the front apron. The shot is executed perfectly; however, the ball stops in its tracks on the apron. Frustration begins to set in, but it is the rub of the green and you move on. A similar situation occurs on No. 2, but this time you decide to fly the ball to the green. The ball hits firmly, takes several hops and is on the back collar. After 18 holes of this guessing game, you decide that it can't be your fault. I know — let's blame the superintendent!

Scene 2: It is the fall, winter, or early spring (depending on your climate) and the weather has finally turned nice for a change. You can't wait to go out and get the rust off the clubs and play a quick 18. The birds are chirping, the sun warms your bones, and the air is fresh. Life is great and so is the golf, until you notice the mowed out temporary green in the fairway on the first hole. After eight more of these "greens" to test your sanity, you decide nine is enough and wonder why you can't always play the regular greens. I know — let's blame the superintendent!

Believe it or not, these two scenes reflect a glaring weakness of one of the most important, yet overlooked, portions of the golf course — the aprons or approaches in front of the greens. Let's take a closer look at the problem and offer simple solutions that can fall within any budget to reduce player complaints. After all, who wants to hear, "It's the fault of the superintendent"?

What is the Apron, and Why is it so Important?

You will not get an argument from anyone that the putting surfaces constitute the highest priority for golfers. With one half of the shots in a hypothetical "perfect" round designated as putts, it is extremely important that putting greens be as smooth and consistent as possible. The practices of light and frequent topdressing, vertical mowing, grooming, low mowing, spoon-feeding fertilizer, rolling, and careful irrigation have all been practiced for years to produce the surfaces desired by the majority of the players. By throwing in the more recent change to spikeless alternatives and the use of growth regulators, is there any reason for anyone to miss a putt? Oh yeah, I forgot that little *ability* issue!

While the putting surfaces require 50% of the strokes on their surfaces in a hypothetical perfect round of golf, another 25% are hit *to the greens*. This represents the second highest percentage of required shots; thus, the area that surrounds the greens should receive the second highest priority for

Mowed-out fairways for "temporary" greens are acceptable for a short time, but they shouldn't be mistaken for "alternate" greens.

Aeration and heavy topdressing are used to prepare approach areas for use as temporary greens.

maintenance. This area encompasses the bunkers, the rough, and the collars that surround the greens on both sides and to the rear.

All three of these locations are important. None is as important, however, as the area directly in front of the greens. The 10-15-yard apron, including the collar, is simply too vital to overlook based on its importance on how the game is played when dry conditions exist and in providing a highly attractive alternative for the *temporary* syndrome associated with mowed-out circles on the fairways. Do you have one of the scenes described earlier played out on your golf course year in and year out? Do you notice lots of ball marks directly in front of the greens? Are you forced to stretch your sanity when dealing with temporary greens during the winter months? If you answered yes to any or all of the above, perhaps the following program can give both the golfers and the maintenance staff more tranquility as they address this less-than-easy game.

Treat the Aprons Like Greens — to a Point!

One of the great things about the golf industry is the way the golf course maintenance equipment manufacturers listen to and respond to the needs of the golf course superintendent. Over the years, many labor-saving devices have been invented and many examples of high-quality mowers have hit the market during the past decade. At the same time, the cost of golf has risen dramatically along with the predictable demands for more "perfection" as witnessed every weekend on more than one major television network. Where will it stop? Can't answer that one, but there are certain practices used during the past decade that make sense for every golf course, while not breaking the budget. One of these practices is the philosophy of treating the aprons (10-15 yards in front of the greens) the same as the greens. The arguments against this practice have been heard many times, and include:

- "We don't have the labor."
- "We don't have the equipment."
- "We don't have the time."
- "We don't have the . . . ."

Before going forward, go back and reread the subtitle to this section, "Treat the aprons like the greens — *to a point.*" The proposal for upgrading the aprons does not including rolling, vertical mowing, grooming, or changing mowing heights. If you are already using growth regulators, following careful irrigation practices, and spoon-feeding, these programs should not change. Assuming the aprons on your golf course are already well drained, the only practices that need to be focused on are regular aeration and topdressing. Now, many of you may be saying, "But I already aerify the aprons twice yearly, followed by topdressing." Good start! Now expand the topdressing program to the same schedule as the greens (every two to four weeks, depending on the growth rate) to minimize the impact of excess thatch. Still suffering from the "we don't have the" syndrome? Golf course equipment manufacturers have come to your rescue.

Aeration and Regular Light Topdressing — the Key to Quality Aprons

As noted earlier, golf course equipment manufacturers have been very responsive to the needs of the golf course superintendent. When superintendents mentioned that a faster method of topdressing greens was

By regularly topdressing the approach areas, a green-type profile can be established over time.

needed, larger drop-type topdressers were introduced. When superintendents said that still faster units were needed, spin topdressers were introduced. Finally, when superintendents asked for topdressers that were fast, accurate, and have the ability to spread wet sand, the manufacturers went to work and have produced outstanding equipment that has revolutionized green topdressing. These new spin units have taken away the "I don't have enough labor, time, and equipment" excuses and replaced them with aprons that are now of the proper firmness to accept an intended "bump-and-run" shot. Soft, thatchy aprons have been replaced with upper surfaces that are similar to the greens, and localized dry spots have been reduced. In short, if you have not already adopted this program, give it a "spin." You and your players will appreciate the results.

Wait! There's Still More!

If improving the aprons for summer play through regular aeration and frequent topdressing isn't enough of a compelling reason to consider this modification in your program, how about those of you still saddled with the temporary greens during the fall, winter, and spring? The other major advantage of upgrading the aeration and topdressing program during the growing season is the ability to change from the temporary philosophy to an alternative approach. A temporary green is just what the name implies. It won't be around long and is just a stopgap measure until the frost, frozen, thawing, or excessively wet conditions are gone. While it should be noted that golf courses should remain closed during frost, thawing, and wet conditions, there are many areas of the country that could use "alternate" greens during frozen times of the year or when greens require a rest for maintenance. The very nature of the word "alternate" implies a site that is nearly equal to the regular green. Based on personal experience and the observations of many, the use of alternate greens greatly reduces complaints and slows down the desire to get back on the regular greens before they may be ready for play. In addition, using the aprons as alternate green sites brings the bunkers into play and can often produce some very interesting shots over or near water hazards. Finally, the need to prepare 18 temporary green sites on selected fairway areas is eliminated since the aprons are already treated like greens and the mowing heights are generally slightly lower than the fairways.

Who enjoys playing golf with this type of condition?

Is there a downside to this two-for-the-price-of-one program for the aprons? Of course. The aprons will experience additional wear and some turf loss during the winter; thus, the larger the area topdressed and aerified, the less potential for damage. The mowers that are used to cut the aprons during the growing season will become dull faster and cause the mechanic more grief, but the upside is hard to overlook. Inevitably, some players will hit shots that will land on the regular greens. With the exception of frost, however, no long-term damage should occur since it is concentrated traffic that causes problems on greens during the off-season. Simply letting the players putt off the greens onto the aprons is far more acceptable than trying to make a putt on a mowed-out patch of fairway. Finally, not all aprons will be conducive to this idea since so many greens are either elevated or heavily contoured in front of the greens. These holes obviously will require a different approach that should match the other alternate greens.

Generally speaking, the lack of regular aeration and light topdressing on the aprons arguably has been the most overlooked area of maintenance on golf courses for several decades. While greens and bunkers demand hours of daily maintenance, taking the funds and the time to upgrade the aprons will pay great dividends down the road. You, too, can change the insanity of temporary greens into the sanity of alternate greens with this modest program.

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TREES vs. TURF

Manage the trees on the golf course to provide healthier turf.

by JACK SWAYZE

Pruning tree roots and installing a bio-barrier prevent future tree root encroachment into the green.

TO A GOLFER, few things are as satisfying as playing a good game of golf on a picturesque golf course. Not only do players come to a course for the sport of the game, but also to appreciate the calming beauty that a golf course can offer. To drive a ball down a fairway lined with mature trees is just about as good as it gets.

Besides defining the fairways and adding character to a golf course, trees provide shade for player comfort and a degree of safety from errant golf shots. From an architectural standpoint, trees are incorporated into a design as strategic play elements. For example, trees are used to help indicate the course routing by creating the dogleg holes.

Overplanting Trees

Although an abundance of trees may at first seem like a positive attribute, too many trees can cause problems. Tree overcrowding is a common occurrence on golf courses for several reasons. Many times trees are planted for "instant gratification" without thought of their coverage once they have matured. Also, overcrowding is commonplace on older golf courses where additional trees have been planted each year. At times, the number of trees planted is increased to compensate for the lack of tree size. If these trees are not thinned out at a later time, overcrowding and distorted growth can occur. Numerous tree and turf problems are self-inflicted due to a lack of understanding or inadequate planning. This snowball effect eventually leads to more tree overcrowding.

Likewise, in an effort to use every existing tree, new golf course construction projects with native stands of trees are also likely to be overcrowded from the very start. As would be expected, the turfgrass grow-in is substantially slower due to the shade.

Conversely, many trees die as a result of golf course construction when grade changes occur from cut and fill. Unfortunately, many of these trees may have had strategic value and will have to be replaced. Better planning in the beginning stages may have saved them.

Aerial photographs depict a different perspective of the trees that line a course. As time passes, the trees grow larger to the point that they can affect play. Meanwhile, misinformed committee members continue to plant more trees as future replacements. The net result is overcrowding with too much vegetation. This heavy vegetation then creates challenges for successful turf management. Poor turf quality arises because the trees have a competitive advantage over the turf.

Tree Problems

Trees can present a competition problem in the turfgrass growing environment. Many species of trees have root systems that can extend outward two to three times the height of the tree. Since the majority of the tree feeder roots are in direct competition with the turf within the top foot of the soil, the trees rob vital nutrients and water from the turf. In addition, the tree canopies physically reduce or block air movement, which can lead to increased disease and algae pressure. Oxygen is a single limiting factor for root depth.

Due to their genetic code, trees grow larger than turf and develop a much larger root system that can extend great distances. Tree roots will invade greens, tees, fairways, and bunkers, given the opportunity, and can grow at a rate of more than six feet in distance per year. Large trees can easily have a root system covering more than an acre and often extending well into your managed turf.

Many times, tree species are planted that are not appropriate for use on golf courses. Some species have dense canopies of foliage with low branches. This makes it impossible to grow healthy turf because of insufficient available light, and it is difficult to mow under the trees. Other trees have shallow or surface rooting characteristics that can be a safety hazard to a player if he hits the root while making a shot. These shallow-rooted trees also damage mowers with their exposed roots.

Some trees are extremely messy with fruit or exfoliating bark. Oftentimes, trees will drop cones or pods that can wedge into the rollers of mowers, producing a poor quality of cut. Obviously, this requires increased labor that could be better appropriated to maintaining turf instead of tree cleanup.

Tree Maintenance

Physiologically, trees function the same as turf. However, they do differ because trees have woody tissue connecting the root system and the canopy. The trunk and limbs that form the canopy continue to grow into the shape and form dictated by its genetic code and in consideration of available sunlight and other site conditions. Just like turf, trees will respond to good care. Their requirements for water, nutrients, and oxygen are the same as turf, and they are opportunistic. The cultural practices that are required to maintain healthy turf are similar for trees: regularly scheduled fertilizer applications, watering practices based on the evapotranspiration (ET), and aeration completed several times per year.

Managing trees on the golf course should be for agronomic benefit as well as for aesthetics. Too often, golf course tree management falls solely into the aesthetic category because the overall benefits are not well understood. Understanding the competition that exists between trees is essential. The trees compete with each other for the same needed elements; the strong survive and grow, and the weak trees die.

There is a strong argument that fewer trees may be better not only for the golf course turf, but also for the remaining trees on the golf course. Fewer trees obviously require less maintenance and often can provide the same strategic golf value with a proportionately less negative impact on the turf. Fewer trees also require less water if the overall tree biomass is less.

Water Requirements

Like turf, tree water requirements are dictated by leaf surface area. The more area, the more water is required to sustain the plant. Temperature, wind, humidity, sunlight, exposure, and season also affect water usage by increasing evapotranspiration. Obviously, dormant turf or trees require less water. ET is calculated similarly for trees as for turf, except that the trees' leaf surface area is proportionately greater and is more exposed due to height. Annual growth results in more canopy each year. More tree growth means that more water is required. Localized dry spots in the turf show up easily during the hot summer months and are very often tree related.

Small seedlings or small container trees may require only a few gallons of water per day for survival or growth. Conversely, large trees may require hundreds to more than a thousand gallons per day depending on the ET rate. Multiply the number of trees on your course by the average gallons needed per tree per day. You may be surprised at the enormous amount of water needed to support the needs of the trees in addition to the needs of the turf.

Developing a Tree Inventory

A sound approach for managing trees on the golf course is to develop a comprehensive tree management plan. It should take into account the agronomic issues of the turf as well as those of the trees. A tree inventory is an excellent starting point that will evaluate your important trees and create a location map and a corresponding database of tree management information. With today's use of Global Positioning System (GPS) and Geographical Information Systems (GIS) technology, the creation of accurate site maps has become greatly simplified.

The tree management plan should be targeted as a long-term goal. If water conservation is an issue, then the tree management plan should address this goal. Emphasis would then be on strategic removals and pruning to reduce the water requirements for the trees. The plan should also include suggested removals, pruning, and other special arboricultural needs, as well as help establish priorities and develop budgets. Safety and liability issues should also be noted and addressed. Courses that have implemented sound tree management programs have seen value-added results with immediate improvements in their turf and playability. The aesthetic improvements can be dramatic, too!

A Working Model

BraeBurn Country Club, in Houston, Texas, initiated a comprehensive tree management program in 1999 with dramatic results. First, aerial photographs of the golf course were digitized so that all of the course features could be recognized. Second, information was collected regarding each tree on each golf hole. For example, tree caliper, species, current health, and recommendations for improvement were coded into a hole-by-hole analysis workbook. Third, a group comprised of the Green Committee, superintendent, general manager, and myself initiated a pilot program to show the general membership what all would be involved. Trees were trimmed, moved, and removed on three holes. This process took approximately one month from start to finish. Shortly after the project was finished, 70 mph winds ripped through Houston and damaged trees and numerous golf courses in the area. Oddly enough, the trees that had been trimmed on the three holes at BraeBurn Country Club suffered no damage as compared to the trees on the rest of the property. The general membership was surprised to see that the tree management program actually helped save essential trees. Consequently, the club funded the tree management plan for the rest of the facility.

Conclusions

After developing a golf course tree management program, a golf course tree-planting plan can be designed with an emphasis on "the right tree in the right place." Tree species selection should be made based on what is appropriate for golf playability, turf quality, and turf and tree maintenance. Tree planting plans are also great for developing memorial tree programs, if they are properly planned and managed. The plan will help direct future tree planting on the course and ensure that your turf management programs and playability are not compromised with an incorrect tree species being introduced or planted in the wrong location.

Many turf problems and playability issues can be alleviated if proper planning and/or planting takes place. A better understanding of trees (including growth potential and maintenance requirements) and their relationships to turf can greatly impact and improve future turf quality, and can help reduce turf maintenance costs for the future.

All too often, course officials throw money at problems in an effort to correct the situation. Unfortunately, the symptoms are treated rather than the problem being solved. Implementing a good tree management program can help pinpoint the problems and provide cost-effective solutions for improving the turf as well as the trees. Trees are a very large and dominating part of the golf course ecosystem. Both trees and turf require sound management practices in order to optimize playing conditions. Incorporating tree management as a vital constituent of your course management program will help ensure better playability and healthier turf.

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Leaching for Salinity Management on Turfgrass Sites

Where salts are a problem, leaching is the answer.

by R. N. CARROW, M. HUCK, and R. R. DUNCAN

Well water can vary greatly and change over time. Regular monitoring of well water is necessary to prevent undesirable contamination. Here brine has entered the water supply through a damaged well casing.

"*SALINITY MANAGEMENT" is synonymous with leaching of salts.* Leaching is the single most important management practice for alleviating or preventing salt stresses on turfgrass sites. Especially when the irrigation water contains appreciable salts, turfgrass managers must operate from a mindset of "*keep the salts moving downward!*"

Although the principle is simple, achieving an effective leaching program that keeps salts moving past the rootzone is complex. Salinity management is influenced by: salt type, soil factors, water quality/quantity, rainfall, turfgrass species and varieties, and time of year.[1,4,9] The approach in this article is to discuss each of these factors, using typical field situations as practical examples.

Which Salt Problem?

1. *High total salinity is the most common and injurious salt problem* (i.e., saline or saline-sodic soil). It is measured as electrical conductivity (EC) of irrigation water (EC_w) or within soils (EC_e, from a saturated paste extract)[1,3,4]. When the total soluble salt level in the rootzone becomes excessive, turfgrass water uptake is reduced, a situation often referred to as *physiological drought*. This salt-induced drought stress causes typical drought symptoms, including wilting and reduced growth rate, even though soil moisture may appear to be adequate. As the stress continues, grasses often start to exhibit chlorosis and decline in quality.[1,9] These symptoms are often mistaken for disease injury.[9]

Leaching of excessive soluble salts is the easiest of the various salt problems to alleviate. Since the salts are soluble and the majority are in solution when the soil is well irrigated, removal of these salts requires the least quantity of water and time. *Only sufficient water applications are needed; amendments will not improve salt movement unless* *other specific problems exist with the soil or water.* With sufficient water moving through the soil, leaching may require 1 to 4 weeks for reclamation purposes. However, accumulation of excessive soluble salts can rapidly reappear due to high salt additions from irrigation water not followed by ample leaching, as well as from soluble salts moving by capillary rise from below the rootzone up into the root area.

2. *Excessive sodium (Na) levels within the soil* can lead to specific ion toxicity to root tissues *and* to deterioration of soil structural (i.e., sodic or saline-sodic soil).[1] The latter condition is evaluated by the soil SAR (sodium adsorption ratio), the SAR_w (SAR of irrigation water), and RSC (residual sodium carbonate) value of irrigation water.[3]

The effects of sodium ion toxicity on root tissues of grasses and high total salinity result in greater expression of drought stress symptoms. Soil structure deterioration from excess Na^+ on soil colloid (clays, colloidal organic matter) exchange sites causes: a decline in water infiltration/percolation/drainage; low soil O_2, which further limits rooting; waterlogged and poorly drained soil; and, sometimes, black layer symptoms.

Leaching of Na^+ requires addition of a relatively soluble Ca^{+2} source to displace the Na^+ from the soil cation exchange sites. When this happens, the Na^+ goes into solution and can be leached.[1] *It is important that a soluble Ca^{+2} source be added whenever leaching with a Na-laden irrigation water source is conducted. If not, the Na problem can be compounded by the leaching of all remaining Ca^{+2}, allowing replacement with Na supplied by Na-laden leaching water, and causing a complete sealing at the soil surface.*

Compared with the removal of high total salts, a much longer time period is required and more water must move through the soil profile. Generally, for the reclamation of a Na-affected site, a year or more may be required to alleviate the Na-induced structural problem, though only 1 to 4 weeks are needed to alleviate the specific ion toxicity threat. Obviously, preventing a sodic condition from forming is very important and is much easier than reclaiming a sodic soil.

3. *Toxic soil levels of the salt boron (B)* is another salt-related problem that requires leaching. Since B is adsorbed to soil particles, two to three times the leaching water volume is necessary compared to the quantity needed for removal of total soluble salts. *In conjunction with leaching, collection and off-site disposal of clippings can assist in reducing B since it is accumulated in turfgrass leaf tips. This strategy can also be used with total salt and sodium problems as a supplemental method of salt reduction.*

Salt Factors

A number of soil characteristics influence salt and water movement/retention and, therefore, leaching practices. Major differences in soil properties are especially apparent when comparing *sandy soils* (i.e., sands, sandy loams, loamy sands) *to fine-textured types* (i.e., containing appreciable

A distinct layer in the profile is inhibiting water movement, resulting in black layer development near the surface. Frequent core cultivation is needed to keep water and salts moving down through the profile.

amounts of silt and clay). Sandy soils are typical of high-sand-content greens, while fine-textured types are representative of pushup greens (native soil greens), fairways, and many tees.

1. *Cation exchange capacity (CEC)*, the ability of a soil to retain cations, is much higher for fine-textured soils than with sands. As a result, less total soluble salts, Na^+, or B are required before CEC sites of sands are adversely affected compared to fine-textured soil CEC sites, and these salts start to accumulate in the soil solution where they are more active. Although salts reach adverse levels more rapidly in sands, removal by leaching is also more rapid.

2. *Macropores*, soil pores with a diameter > 0.12mm, are much more prevalent in sands than fine-textured soils. Macropores are critical for rapid water movement into the soil surface (*infiltration*), through the rootzone (*percolation*), and beyond the rootzone (*drainage*). Effective leaching cannot be accomplished without macropores, and macropores must be present throughout the soil profile.

Even a thin zone or layer with few macropores within a soil profile will both limit water movement and result in salt accumulation above this layer. Any soil layer or horizon that inhibits water movement will be a major hindrance to effective leaching — whether it is at the surface (surface compaction) or subsurface (e.g., B horizon, cultivation pan, buried layer from flood deposition of fines, etc.). Cultivation operations that enhance infiltration and percolation (deep cultivation techniques) are done essentially to create temporary macropores. If the cultivation holes are filled with sand, the macropores remain for a longer period of time. Thus, turfgrass managers must be familiar with the entire soil profile and should "visualize" whether macropores exist for effective leaching down to the deep subsoil or to drain lines.

3. *Clay type* has a significant influence on water movement. Non-shrink/swell clays (kaolinite, Fe/Al oxides) are called *1:1 clay types,* and these do not crack when dry or seal by swelling when wet. The benefits of cultivation generally last longer on 1:1 clays than the *2:1 types* discussed below. Also, a higher level of Na^+ is required on 1:1 CEC sites before soil structure begins to deteriorate, usually at > 24% Na saturation compared to > 9% Na for many 2:1 types (montmorillonite, illite). Generally, 1:1 clays are more resistant to soil compaction than 2:1 clays. Because 1:1 clays evolve in humid, high-rainfall areas, they often exhibit a B horizon where clay content is higher due to downward movement of particles over many years. For example, many Piedmont red clays (1:1 types) contain 40% to 50% clay in the B horizon versus 15% to 25% in the surface A horizon, and water movement is slower across the B horizon.

In arid and semi-arid climates, where salt problems occur most often, 2:1 clays predominate. Nevertheless, they can be present in most climatic zones. When drying, 2:1 types are "self-cultivating" because cracks form. Unfortunately, under well-watered to saturated moisture conditions, these clays swell and most macropores are lost. When total salinity problems develop on these soils, deep cultivation and filling the cultivation holes with sand or sand plus gypsum (sodic sites) is necessary to maintain a sufficient number of macropores to at least the depth of cultivation. In contrast, deep cultivation operations are effective for longer time periods on 1:1 clays even without filling holes with sand.

4. *Good soil structure* on fine-textured soils is important for maintaining macropores. As aggregates are formed, macropores are developed between aggregates or structural units. Soil compaction from recreational traffic destroys many of the macropores in the surface 3-inch zone, but a well-structured soil will usually have some macropores deeper in the profile. The 2:1 clays are much more prone to soil compaction than the 1:1 types.

Sandy soils with > 85% sand content exhibit sand particle-to-particle contact, which creates many macropores and gives the soil good resistance to compaction. If excessive fines are added to the soil or excessive organic matter fills most of the macropores, infiltration rates can decline, but generally, sands have high infiltration rates conducive to leaching of salts. Although high Na^+ content does not cause "structural breakdown" of single grain sand particles, it does cause any colloidal particles (clay or organic matter in nature) to be dispersed and become susceptible to particle migration. Pond, lake, or river water with high turbidity can contribute fines during irrigation. Often, these fine particles accumulate at the normal depth of irrigation water penetration and can cause a layer and eventually may induce black layer formation. This sequence of events would then inhibit salt leaching.

As noted previously, high levels of Na^+ cause structural deterioration of fine-textured soils. This is especially serious on 2:1 clays, since they often exhibit poor drainage even under low Na^+ due to their swelling/sealing nature. High Na^+ content further decreases water movement throughout the whole soil profile.

5. *Capillary rise* of the soil solution and any dissolved salts in the solution occurs in the *micropores* (pores of < 0.12mm diameter) and can result in major redistribution of salts within the soil profile. When ample water is applied to cause net downward leaching of salts, salinity near the surface is similar to the initial irrigation water salinity level, but salinity then increases with depth. Under high evapotranspiration (ET) conditions, salts may start

Table 1
Evapotranspiration averages by environment for turfgrasses under well-irrigated conditions for different climate conditions

Climate Situations	Average Evapotranspiration* (inches per day)
Cool humid	0.10 to 0.15
Cool dry	0.15 to 0.25
Warm humid	0.15 to 0.20
Warm dry	0.20 to 0.25
Hot humid	0.20 to 0.25
Hot dry	0.25 to 0.35

*The actual ET varies with grass species/cultivar, wind speed, management level, etc., but these values provide "ballpark" estimates. Also, as soil moisture level declines, ET decreases dramatically.

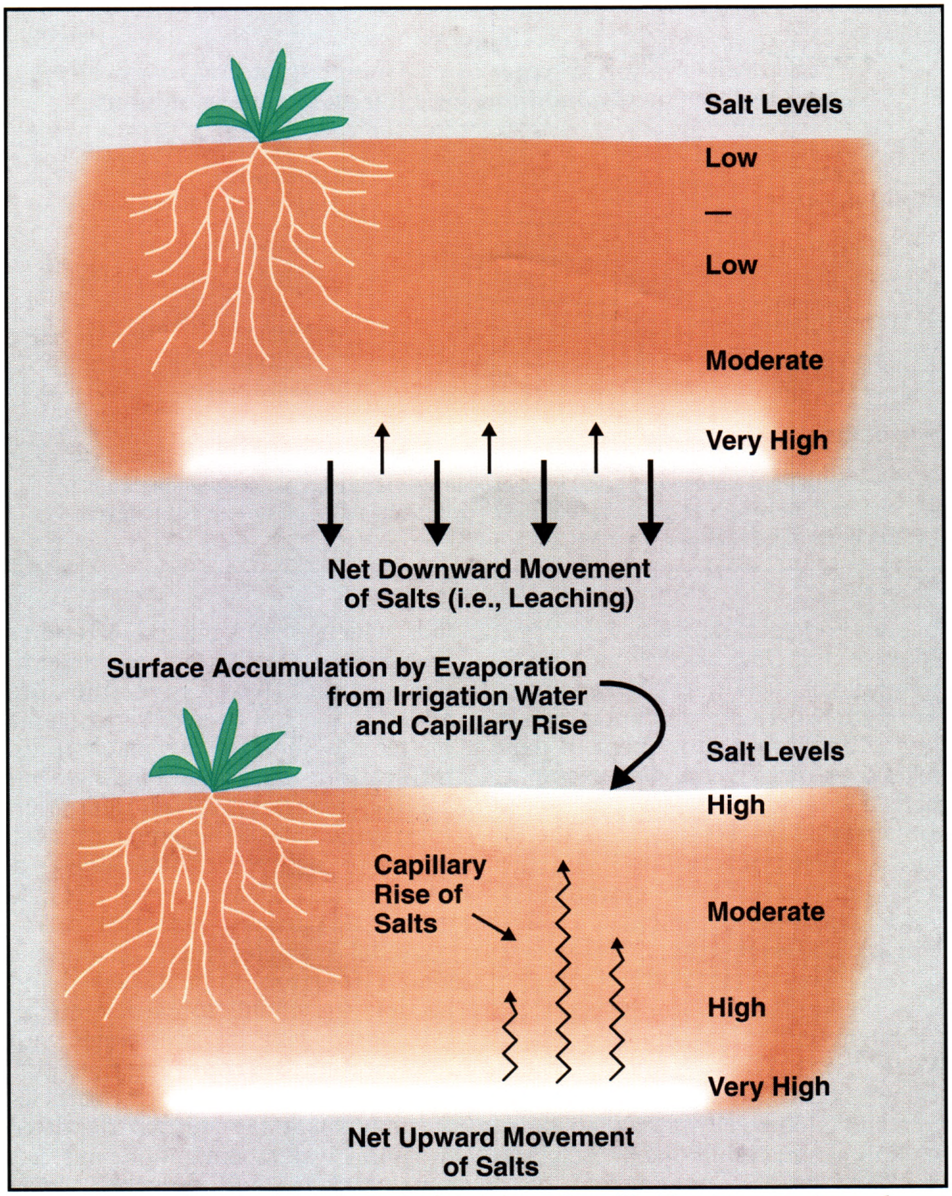


Figure 1. Examples of salt levels throughout the soil profile. Top: Represents good leaching conditions with adequate leaching requirement (LR) applied. Bottom: Represents what happens when insufficient water is applied in midsummer with high evapotranspiration (ET) conditions.

to rise by capillary action and by plant transpiration if the leaching fraction is less than ET (Table 1). Salts then will move back into the rootzone and start to accumulate near the surface (Figure 1).

Capillary rise of salts will be more rapid on fine-textured soils than sands because fine-textured soils contain more micropores. Other factors that increase capillary rise of salts are low leaching rates, high ET conditions, and a high water table.

6. *Water table location* is another soil factor that influences salinity control. Turfgrass soils often contain a layer in the profile that inhibits water percolation or drainage. This can create a temporary *perched water table* as water flow is slowed or stopped when the wetting front reaches this layer. Salts then will accumulate above the layer and can rise to the surface whenever low leaching rates and/or high ET occurs. The quantity of water needed to cause net salt leaching in low-ET conditions may not be adequate for leaching under hot, dry situations (Table 1).

Subsurface layers that are 1 to 3 feet below the surface are often overlooked in arid or semi-arid regions where heavy rainfall events that are sufficient to pond water up to the soil surface are rare. But, these *hidden layers* can contribute to major salt accumulation so that when conditions favor capillary rise, the resulting water has very high salinity.

In many turfgrass soils, the layer that limits water percolation/drainage has few macropores. Cultivation depth must penetrate completely through the layer to be very useful for maintaining water flow when excess water application occurs by irrigation or rainfall.

Another type of *perched water table* is found in many high sand content constructed profiles, such as those built with the USGA green construction method. In this case, ample macropores are present but sufficient water is required to break the perched water tension and to initiate rapid drainage or *flushing* of the rootzone. During summer months when ET is high, salts above the perched water table zone may start to rise toward the roots and soil surface if thorough leaching is not practiced. Prolonged drought, high temperatures, and dry, windy conditions can escalate this capillary rise of concentrated salts.

In addition to perched water tables, sometimes the *natural water table level* is near the surface. The *capillary fringe* of semi-saturated water conditions above a free water table is usually 2 to 8 inches for sands and 8 to 12 inches for fine-textured soils. However, high ET conditions and limited leaching can cause salts to rise well above these distances over time. Capillary rise on fine-textured soils is still strongly controlled by climatic conditions (i.e., ET) at a depth of 2.5 to 3.0 feet and possibly down to about 5.0 feet.

Another problem with a water table relatively near the surface occurs when poor irrigation water quality requires a high leaching fraction. Over time, the water table may rise even higher and cause massive salinization of the rootzone. On sites where shallow water tables may rise, the turf manager should investigate means to lower the water table.

7. *Total pore space (pore volume, PV)* of a soil also influences salt leaching. Soils with higher PV require more water to leach the same quantity of salts.[7] The PV range of sands, loams, and clays is about 35% to 40%, 40% to 50%, and 45% to 55%, respectively. For a soil depth of 12 inches, 1 PV of applied water would represent 4.6 to 4.8 (sands), 4.8 to 6.0 (loams), and 5.4 to 6.6 (clays) inches of irrigation. Thus, more water is required to leach fine-textured soils than sands.

Water and Irrigation Factors

1. *Irrigation water quality* strongly influences the quantity of water needed to leach salts, with more water required as water salinity level increases. The *leaching requirement (LR)* is the minimum amount of water that must pass through the rootzone to keep salts (i.e., keep salts moving) within an acceptable range. Thus, LR is used for *maintenance leaching* where sufficient water is applied to maintain soil salinity at an acceptable level.

Several methods are used to determine the LR[1]. The method of Rhoades[6] provides a good approximation and is based on the irrigation water salinity level (EC_w, dSm^{-1}) and grass salinity tolerance using the *threshold EC_e* (the soil salinity, EC_e, at which growth declines compared to growth under non-saline conditions), where (see Table 2):

$$LR = \frac{EC_w}{5EC_e - EC_w} = \text{percent extra water above ET to leach salts}$$

Assuming the initial rootzone salinity level is acceptable, *when the LR is not sufficient to maintain salt leaching, two adverse salt responses occur:* a) first, salts applied in the irrigation water start to accumulate within the surface few inches, and b) capillary rise of salts from deeper in the soil and beyond the rootzone starts to bring salts back into the rootzone (Figure 1). Oftentimes, this zone of accumulated salts has a very high EC_e and upon reaching the lower rootzone can induce rapid salinity stress. When this happens, alleviating salinity stress (physiological drought with reduced water uptake for transpirational cooling) now requires much more applied water than the LR amount because it is a reclamation problem (as well as a serious threat to job security).

This scenario is most often observed on high sand bentgrass/*Poa annua* golf greens irrigated with water of medium to high salinity. In addition, turf managers who apply water with relatively low total salt levels (500 to 600 ppm) may experience this situation under extreme environmental conditions. The turf manager may be achieving adequate leaching in the spring and early summer using ample irrigation or rainfall. However, by midsummer, three events can impede leaching: a) hot, dry weather increases the ET and increases the quantity of irrigation needed just to maintain soil moisture (Table 1); b) turf roots start to die back; and c) turf managers shift to light, more frequent irrigation which does not supply sufficient water for leaching. The process depicted in Figure 1 (bottom) is initiated.

Light, frequent irrigation increases salt accumulation in the surface zone, where most of the roots are located. Also, salts rise by capillary action into the rootzone from: a) a high salt zone common in pushup greens, or b) the perched water of a USGA green that is not adequately flushed. Injury normally appears on the most elevated, open, and exposed greens where high ET conditions prevail due to high solar radiation and wind movement. Since the bentgrass/*Poa annua* is now under high temperature stress, the salt-induced drought is a serious additional stress.

By being aware of this sequence of events, the turf manager can apply an extra leaching irrigation every 1 to 4 weeks to avoid salt accumulation. The frequency between leaching events will vary depending upon water quality, rootzone depth, and the threshold EC of individual turfgrass varieties. The leaching frequency and threshold EC can be accurately determined by use of an inexpensive portable EC meter.[10] *EC at the soil surface and throughout the profile can be monitored regularly (daily if necessary) and, as the threshold EC is reached, leaching can be initiated to purge the perched water table.*

A practical method to assure that the perched water table has been completely purged is to locate the outflow drain line exiting the green cavity and install an inspection port. Drainage flow can be observed, and samples collected and tested with the portable (EC) meter. Once the EC of the drainage water is at or near the EC of the irrigation water, then leaching has been completed. Although native soils may require 1 to 4 weeks to reclaim, well-drained sand constructed putting green rootzones with perched water tables can often be reclaimed in 1 to 3 days.

Between leaching events, additional irrigation may be needed on a light, frequent basis until turf roots regenerate, which may not occur on bentgrass/*Poa annua* greens until cooler weather arrives.

2. *Reclamation leaching* differs from the previous maintenance LR concept, which focused on maintaining salinity levels at an existing acceptable level. In reclamation, a higher quantity of water is required to decrease rootzone salinity to acceptable levels. Once this acceptable level is achieved, the LR irrigation approach (maintenance leaching) can be used, since it requires less extra water. The reclamation approach occurs in two primary situations in turfgrass management: a) when a seriously salt-affected soil (e.g., highly saline and/or sodic condition) must be leached of excess salts before grass can be established, and b) when a turf manager has not main-

Table 2
Determination of the Maintenance Leaching Requirement (LR)
(after Rhoades[6])

Concept: Once the soil salinity level in the turfgrass rootzone is at an acceptable or desirable level, the leaching requirement (LR) approach is used to maintain this level. The "leaching requirement" (LR) is the minimum amount of water that passes through the rootzone to control salts within an acceptable range. A good formula to determine LR is:

$$LR = \frac{EC_w}{5EC_e - EC_w}$$

where EC_w = irrigation water salinity (dSm^{-1})
EC_e = threshold soil salinity at which growth starts to decline for the turfgrass on the site. Carrow and Duncan[1] has an extensive listing.

Example: For turfgrass with a threshold EC_e of 6 dSm^{-1} and irrigation water that has an $EC_w = 2\ dSm^{-1}$.

$$LR = \frac{(2)}{5(6) - 2} = 0.0714$$

which means that the LR is 7.1% more irrigation water volume than that needed to meet ET needs. Thus, if irrigation of 0.50 inches of water is required to replace soil moisture lost by ET, an additional 7.1% or $(0.50 \times 0.07) = 0.035$ inches of water would be required for a total of 0.535 inches to maintain a particular salinity level. It should be noted that a *more saline irrigation water* with higher EC_w or a *less-salt-tolerant grass* would *increase the LR.*

tained an adequate LR and the rootzone has increased in salinity to severe levels. This latter situation is most likely to occur during hot, dry summers when ET rates have increased, but the total water applied for ET + LR has not been adjusted to keep up with actual ET. Cool-season turfgrasses subjected to this sudden and intense salinity shock (a combination of drought, high temperature, and greater wear stresses from slower growth, all induced by salts) often do not survive. The take-home lesson for this type of stress is *prevention* by adequate, continual application of sufficient LR water to keep salts moving downward and away from the turf root system.

Reclamation leaching needs can be estimated by the procedure presented by Rhoades and Loveday[7] (Table 3). This procedure takes into consideration: depth of leaching, desired EC_e, current or initial EC_e leaching water quality, and soil type.

Once the depth of water (D_w) required for leaching is determined in terms of "inches of water to apply," then *the influence of rainfall* can be factored into the situation. For example, in Table 3, the situation indicates that 10.4 inches of water would be required for reclamation where the leaching water has an $EC_w = 1.5$ dSm^{-1}. If an EC_w of 0.10 dSm^{-1} is used for rainfall, then the $D_w = 3.32$ inches of rain to achieve the same degree of leaching as 10.4 inches of $EC_w = 1.5$ dSm^{-1} irrigation water.

When comparing the D_w leaching needs using an irrigation water with $EC_w = 1.5$ dSm^{-1} quality versus rainfall (Table 3), it is clear that water quality has a similar important influence on reclamation leaching and on maintenance LR. A second implication is that turfgrass managers should use their rainfall periods to maximize leaching. For example, following a good rainfall period when substantial salt leaching has occurred and has adequately leached salts below the rootzone, do not stop a maintenance LR program to conserve water. Instead, the LR fraction should be continued to prevent salts from rising back into the rootzone. If resalinization of the rootzone is allowed to occur, a reclamation leaching with substantially more water is required to achieve what the rainfall event had accomplished.

In the previous discussions on maintenance LR and reclamation leaching needs, the emphasis has been on total soluble salts and their removal. Normally, a site contains an array of soluble salts. However, if the water quality test and soil tests indicate that Cl is the dominant salt ion, the amount of water required for leaching this ion is less than for other total soluble salts due to the high mobility of Cl. As an approximation, leaching needs could be reduced by about one-third for a trial period and then readjusted based on the results. Reduced leaf tip burn symptoms on landscape plants would be a good indication of your leaching success.

A second means of estimating reclamation leaching is noted in Table 4. This method considers soil type, percent of total salts to be leached, and depth of leaching. It does not, however, take into account leaching water quality.

3. *Irrigation scheduling for effective leaching.* A highly efficient, well-zoned irrigation system is a priority for effective leaching of salts. The method of water application, even with a well-designed system, though, influences the quantity of water required for effective

Table 3
Determining Reclamation Leaching Needs
(adapted after Rhoades and Loveday[7])*

The following equation is used:

$$D_w = k \times D_s \times \frac{EC_{eo} - EC_w}{EC_e - EC_w}$$

where:
- D_w = depth of water to apply for leaching (feet)
- D_s = depth of soil to be reclaimed or leached (feet)
- EC_e = final soil salinity desired. *This value is usually the threshold EC_e for the turfgrass being used or somewhat less than the threshold EC_e*
- EC_{eo} = initial or original soil salinity
- EC_w = salinity of irrigation water used for leaching
- k = factor that varies with soil type and water application method (efficiency of irrigation system)

For sprinkler irrigation applied by pulse irrigation to allow drainage ranging from 1 to 2 hours (sands) to 2 to 8 hours (fine-textured soils) between a pulse irrigation event until the total quantity of water is applied:

k = 0.05 for high sand content each with > 95% sand content (i.e., < 5% silt + clay content)

k = 0.10 for all other soils

For continuous ponding or continuous sprinkler irrigation applied to keep the soils saturated during leaching:

k = 0.45 for organic soils

k = 0.30 for fine-textured soils

k = 0.10 for sandy soils

Example: A high-sand-content golf green with an initial soil EC = 8.0 dSm^{-1} (i.e., EC_{eo}) and the turf manager desires a final soil EC = 2.0 dSm^{-1} (i.e., EC_e). The irrigation water used for leaching has an EC_w of 1.50 dSm^{-1} and the desired leaching depth (D_s) is 16 in. to reach the drain tile, where 16 in. = 1.33 ft.

$$D_w = k \times D_s \times \frac{EC_{eo} - EC_w}{EC_e - EC_w}$$

= 0.86 ft. of leaching water

= 10.4 inches of water

- *If the leaching water quality was better* (for example, $EC_w = 1.0$ dSm^{-1}), then: *D_w = 5.6 inches of water.*
- *If the final salinity level (EC_e) was higher* because of a more salt-tolerant grass (for example, $EC_e = 4.0$ dSm^{-1}), then: *D_w = 2.6 inches of water.*
- *If the green was a pushup green* with < 95% sand where k = 0.10, then: *D_w = 20.7 inches of water.*

*Adjustments in the k value for high-sand-content greens are based on experience of Carrow, Huck, and Duncan.

Table 4
Estimated Reclamation Leaching Needs Based on Soil Type*

An alternative to determining "Reclamation Leaching Needs" by the methods of Rhoades and Loveday[7] presented in Table 1 is based on the soil total pore space or pore volume (PV)

Basic Relationships:

Soil Type	PV (%)	Inches of Water Per 12 Inches Soil to Fill PV
Sand (< 95% sand content)	35	(.35)(12) = 4.20
Loamy sand	38	4.56
Sandy loam	42	5.04
Loams	45	5.40
Clays	50	6.00

PV Equivalent of Water Required to Leach 70% of Total Soluble Salts:

Sand (< 95% sand content)	= 0.70
Loamy sand	= 1.00
Sandy loam	= 1.00-1.25**
Loams	= 1.50-2.50**
Clays	= 2.50-4.00**

Example: A high-sand-content golf green with leaching desired to a depth of 16 in. to reach the tile lines. PV = 35% = 4.20 in. of water per 12 in. of soil depth, thus for 16 in.:

$$(4.20 \text{ in. of water}) \times \frac{16}{12} = 5.60 \text{ in. of water to fill the PV to 16 in.}$$

For a high-sand-content green (> 95% sand), a PV equivalent of 0.70 is used to achieve approximately 70% leaching of total soluble salts, therefore:

(5.60 in. of water)(0.70) = *3.92 in. of water should be applied to achieve 70% leaching of salts across the 16 in. soil depth*

If only 50% salt leaching is required, adjust the PV equivalent, for example:

$$(5.60 \text{ in. of water})(0.70 \times \frac{50\%}{70\%}) = 2.80 \text{ in. of water}$$

If a pushup green is present, then PV equivalent becomes 1.25 (assuming a sandy loam, 2:1 clay) and the inches of water per 12 in. soil depth is 5.04 in. Then, for 70% leaching of salts:

$$(5.04 \text{ in. of water}) \times \frac{16}{12} = 6.72 \text{ in. of water to fill the PV to 16 in.}$$

(6.72 in. of water)(1.25) = *8.4 in. of water* applied

*Rhoades and Loveday[7]. PV equivalent values are adjusted by Carrow, Huck, and Duncan based on experience.

**For 2:1 shrink/swell cracking clays, use the higher value, and for 1:1 non-cracking clays, use the lower value.

leaching.[4,7] Potential means to apply water for reclamation or maintenance LR needs are:

• *Heavy continuous water application by sprinklers* where the soil is essentially saturated or near saturation throughout the leaching period. This would be similar to soil conditions that could occur from *heavy rainfall* or *continuous ponding* of water above the soil surface. Water application by any of these methods requires the most water to achieve leaching, especially on fine-textured soils. Under *saturated flow* or near-saturated conditions, water flow is primarily through the larger macropores, and water does not effectively leach between the macropores, i.e., within soil aggregates or micropore areas. On high sand content soils, which do not form aggregates but are more single grain sand in structure, saturated flow works better than on fine-textured soils.

• *Pulse irrigation* occurs when water is applied in increments of 0.20 to 0.33 inches, with a time interval before the next pulse, and this cycle is repeated until the desired quantity of water is applied. Runoff from the soil surface is minimized. Generally, the time interval between pulses is ½ to 1 hour (sands), 1 to 2 hours (loamy sands, sandy loams), 2 to 4 hours (loams), and 3 to 6 hours (clays). A good surface cultivation program, to maintain adequate water infiltration without runoff, will reduce the time required between irrigation pulses.

With this type of irrigation, water flow within the soil is primarily *unsaturated flow,* which moves as a more uniform wetting front downward through the soil profile. Water movement occurs more in the micropores than in the macropores; therefore, leaching is more effective. Wetting agents often aid in maintaining a more uniform wetting front for leaching. In fact, one-third to one-half the water is required for pulse irrigation versus heavy continuous irrigation. A *light, continuous rainfall* can simulate pulse irrigation as long as the rainfall rate is less than the saturated water hydraulic conductivity of the soil (i.e., the infiltration rate when the soil is saturated).

On *high sand content greens*, the surface 1- to 2-inch zone is where the water movement rate generally is the lowest. If a good maintenance LR program is followed, such that salts have not been allowed to accumulate in the surface, periodic surface cultivation to keep vertical "macropores" or holes open across this zone is beneficial to allow rapid water infiltration during heavier rains. Also, maintaining high infiltration rates across the surface zone makes irrigation programming easier, and a pulse approach may not be necessary under these conditions.

If salts are allowed to accumulate at the surface, however, due to insufficient LR, then a pulse approach is necessary. Attempting to implement a heavy leaching event will result in most of the water flowing through the cultivation holes that penetrate through the salt-troubled surface zone. A pulse approach is better because it allows leaching between holes where salt has accumulated.

4. *Irrigation scheduling to avoid soggy soils is a challenge, especially for fine-textured soils.* When salts accumulate in the surface zone and/or deeper in the rootzone to a point where reclamation leaching is required: a) a good surface cultivation program is necessary to allow rapid infiltration; b) deep cultivation is needed to allow water percolation. Also, this will allow better water penetration during heavy rains, and c) additional drainage, such as tile lines, may be needed to keep the salts moving away from the rootzone.

Reclamation leaching will normally result in temporary soggy conditions for fine-textured soils due to the intensive nature of leaching. Thus, the best way to avoid soggy soils is to avoid being in a reclamation condition. This is achieved by a good routine maintenance LR program that continuously keeps salts leached out of the rootzone. Maintenance LR programs require much less water than reclamation situations and therefore are less likely to create waterlogged or soggy soils.

Following are guidelines for scheduling routine irrigation events on fine-textured soils that include the LR as well as ET replacement components.

• When the irrigation water is moderate to high in salinity, *schedule irrigation so that the bottom one-third of the rootzone is subjected to only moderate moisture stress.* Grasses extract water primarily from the surface two-thirds of their rootzone until the moisture in this zone becomes limited. Since salts concentrate in the soil solution with soil drying, sites irrigated with saline water should be irrigated more frequently (i.e., with less dry-down to induce moisture stress) than non-saline sites. Thus, if a non-saline area would receive irrigation every 7 days with water to replace the 7-day ET loss, then a saline site may need to be irrigated on day 5, with the 5-day ET replacement water plus the additional LR.

• *When irrigation is applied, pulse scheduling is preferred to achieve better leaching and avoid soggy soils.* The interval between irrigation pulses was noted previously as 2 to 4 hours (loams) and 3 to 6 hours (clays), with the longer interval required on compaced sites or Na^+-affected soils (i.e., sodic soils or soils starting to become sodic). Such intervals may only allow 2 to 3 pulse applications per evening at 0.20 to 0.33 inches per application. Thus, it may require two or more consecutive evenings to apply sufficient total water (i.e., ET + LR). Another possibility is to schedule pulses during the daytime when the golf course is closed (often Mondays) as well as during the evenings. For example, from Sunday evening through early Tuesday morning would provide a 32-hour period for pulse irrigation. Consideration for traffic restrictions (golf cars and maintenance equipment) in fine-textured soil areas (fairways and roughs) may be necessary for 1 to 3 days following a heavy leaching.

• *The use of the LR fraction as part of normal irrigation should be a continuous, routine practice,* especially: a) when the irrigation water quality is high in total soluble salts or Na, b) on fine-textured soils but particularly 2:1 clay types, and c) on any sodic or presodic soil. A common reason for resalinization of rootzones or ineffective leaching of total salts/Na is the elimination of the LR application after a rainfall period, followed by redistribution of salts.

• *Application of the LR should start early in the growing season,* if soil salinity is at an acceptable level.[9] If not, then reclamation leaching should be instituted until the soil salinity level becomes acceptable. Thereafter, the LR application should be initiated and maintained. This will prevent the advent of salts accumulating to harmful levels during high-ET summer months when reclamation leaching is very difficult.

5. *Irrigation water quantity* obviously influences leaching effectiveness. Up to this point, we have noted that the *Irrigation Quantity (IQ)* for routine irrigation consists of replacement of soil moisture lost by evapotranspiration (ET) plus LR. However, a third factor influences total irrigation needs. This factor is nonuniformity (efficiency) of the irrigation system. Water application rate must be increased by a *Scheduling Coefficient (SC)* to account for nonuniform water application. Thus, total irrigation quantity required includes:

$$IQ = SC(ET + LR) = \text{inches of irrigation water to apply}$$

where the SC may be a factor such as 1.1 to adjust for nonuniformity of the irrigation system.

On turfgrass sites receiving saline irrigation water, identifying a correct IQ and adjusting the value as the weather changes is essential for good salinity management and high turfgrass performance. *Once an acceptable soil salinity has been achieved, the primary cause of resalinization is inadequate water application (i.e., IQ).* Turfgrass managers are strongly encouraged to think in terms of *quantity of water applied* rather than *minutes of irrigation time.* Salt leaching requires an adequate quantity of water and only by monitoring the quantity of applied water can there be confidence of achieving long-term maintenance leaching.

Huck[5] presents an excellent discussion on *irrigation system efficiency* and design considerations. Nonuniformity of water application may result from several factors, including: a) improper sprinkler head spacing for wind and water pressure conditions, including hydraulic losses from friction and elevation differences; b) incorrect sprinkler or nozzle selection; and c) poor system maintenance such as leakage, sprinkler/nozzle wear, and mixing of nozzles. Adjustments in these factors during design and, if necessary, after installation can improve delivery efficiency and enhance leaching of salts.

Where irrigation uniformity is lacking and cannot be improved due to a poor irrigation system, the use of portable hose-end sprinklers can be an effective method to apply additional water in areas lacking coverage. Ultra-low precipitation rate models are most effective. They are normally placed in the problem area and allowed to operate from dusk until dawn.

Site-specific water management is important for salinity management and to avoid waterlogged areas. Some examples are: a) dual irrigation systems for greens and the surrounds. The ideal system would include the ability to irrigate greens with a different, higher-quality water source, but dual systems, even with the same water source, allow for better scheduling. b) Mounds, berms, bunker tongues, and steep slopes present a problem. West- and south-facing exposures in the northern hemisphere are especially vulnerable to high-ET losses and salt accumulation. On facilities with highly saline irrigation water, irrigation designers should consider how to effectively irrigate water on these peripheral areas. c) On fairways with south-facing slopes where ET is normally greater, zones should be designed to accommodate this need. Portable sprinklers can also be used effectively to specifically leach putting green surfaces and avoid flooding bunkers or saturating green surrounds during the leaching process.[11]

6. *Infiltration, percolation, and drainage of applied water is essential for salt leaching.* The soil profile on each site on a golf course should be assessed in terms of any barriers to water movement, starting with infiltration. Carrow and Duncan[1] present the most common soil physical problems on sandy and fine-textured soils that impede water movement downward through the whole profile. Appropriate cultivation, soil modification, and drainage operations should be conducted to ensure that water (and salts) are able to move downward. Drainage and salt disposal options should also be considered as part of an overall water management plan.[1]

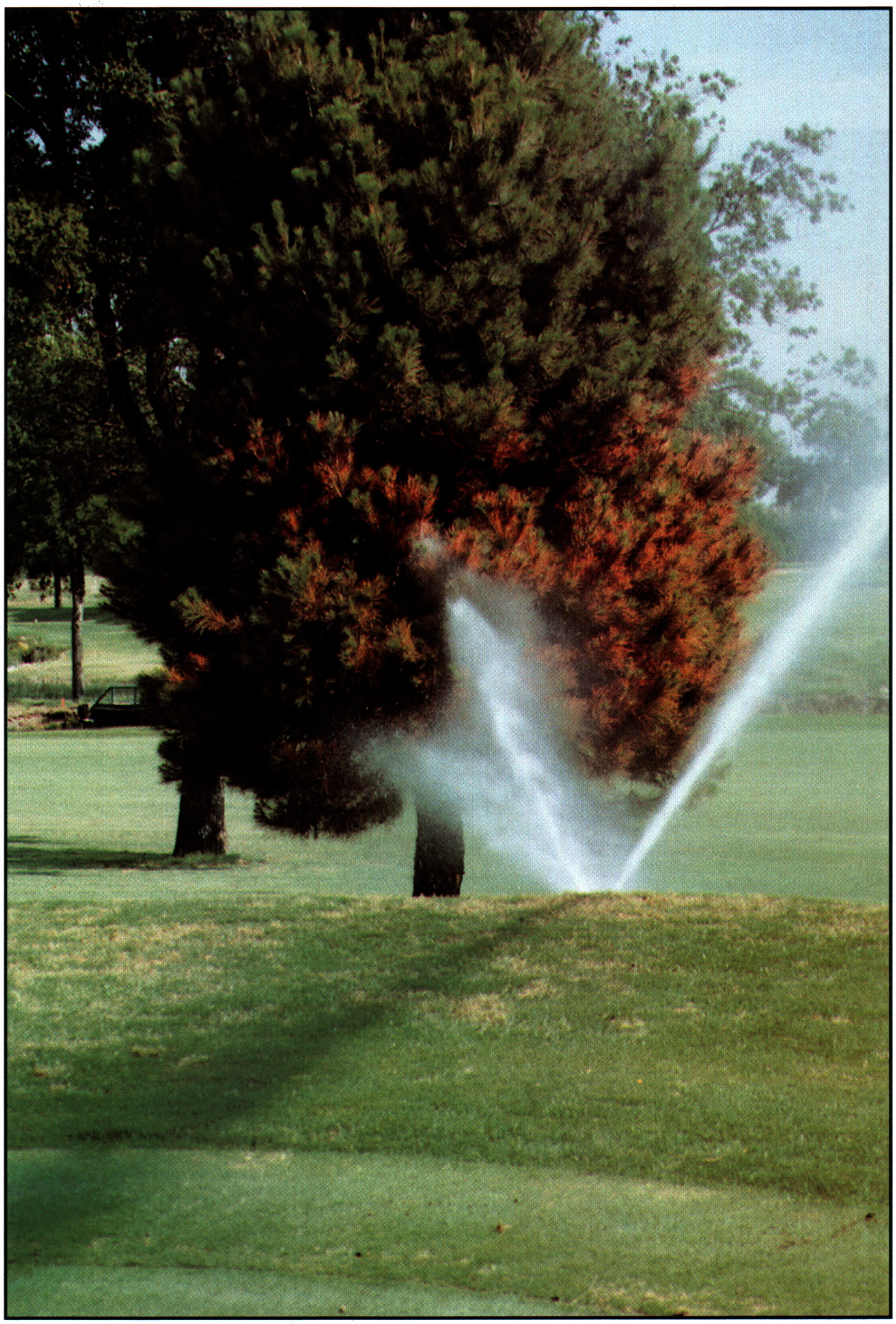
7. *Water and soil amendments* need to be considered to ensure good water infiltration and to facilitate alleviation of sodic conditions on sodic sites. The various situations requiring irrigation water treatment have been discussed by Carrow et al[2] and Carrow and Duncan[1]. Proper amendment selection (for water and soil), application method, and rates are all very important, especially when sodic conditions might occur or are already present. Due to the detailed nature of these subjects, they are beyond the scope of this article. However, treatment of irrigation water or the soil with amendments will be ineffective for alleviating salt problems unless a good leaching program is followed.

Grass Type

Salinity management is influenced by the type of grass, salt types present, soil factors, and water/irrigation factors.

1. *Salinity tolerance of the grass is the most important influence of grass species/cultivar in salinity management.* As demonstrated in the example in Table 1, the LR is influenced by the salinity level the grass can tolerate. The threshold EC_e is used as a guide and is defined as the soil salinity at which growth starts to decline compared to a nonsaline condition.[1] Grasses with moderate to very high salinity tolerance can be irrigated to maintain the soil salinity at greater than the threshold EC_e, perhaps at EC_e of 25% or 50% growth reduction. The grass vigor and ability to withstand wear from traffic should be considered in selecting the appropriate maintenance EC_e.

2. *Turfgrass rooting depth impacts salinity management.* Provided that adequate soil moisture is present in the lower one-third of the root system to avoid salt concentration (i.e., soil moisture is about field capacity in this zone), turfgrass growth is related to average rootzone EC_e, regardless of the salt distribution with in the rootzone. Thus, when monitoring soil EC_e by depth within the rootzone, the average EC_e is the value used to compare with the turfgrass salinity tolerance level selected, such as EC_e for 25% growth reduction.



The effects of high salt levels in the irrigation water are obvious on this pine tree.

Especially with high-saline irrigation water, irrigation events should be scheduled to avoid depletion of soil moisture within the lower one-third of the rootzone. Otherwise, serious salt stress will occur. Irrigation events need to be scheduled more often than on a similar nonsaline site, with the IQ dependent on ET losses since the last irrigation plus the LR. Also, a deep-rooted turfgrass will allow for more days between irrigation events than a shallow-rooted grass.

Rooting depth determines the rootzone that must be leached by the LR. This is the D_s (depth of soil) to be reclaimed or leached in Table 2 and the leaching depth in Table 3.

Monitoring Soil Salinity

Monitoring soil salinity by soil depth is critical for assessing the success of a salinity management program.[1,4] The *soil depth* for monitoring is determined by the rootzone depth. Soil EC_e values within the surface one-third and bottom one-third of the rootzone are the most important. Soil sampling procedures and methods for monitoring field salinity are given by Carrow and

A combination of poor water quality and poor irrigation system distribution has caused severe salt stress injury on this green and surrounds.

Duncan[1] and Hanson et al.[4] On sites with an ongoing salinity problem, obtaining instruments to determine soil salinity in-situ should be considered. J. D. Rhoades of the U.S. Salinity Laboratory has developed two procedures[4]: a) the four-electrode salinity probe, which can be used to measure salt levels at different depths, and b) the electromagnetic conductivity meter for rapid surface measurement, including down to a depth of 3 to 4 feet. Vermeulen[10] also discusses an inexpensive conductivity meter useful for both monitoring drainage water and soil salinity in the field.

Summary

Development of a salinity management program requires the consideration of a number of soil, water, and grass factors. *Leaching of salts is the most important component of any salinity management program.* Unless salts are consistently leached from the rootzone, resalinization will occur from irrigation salt additions and capillary movement from below the rootzone. The peak time of year for massive resalinization and the accompanying decline of turf performance is often mid- to late summer. This is the least favorable time to experience salinity stress and the most difficult time to institute reclamation leaching. *The best option for managing salinity is a continuous, routine maintenance leaching program using an adequate LR.* The most common reason for not applying sufficient irrigation water volume for leaching of salts is underestimating the daily ET requirement for replacement of soil moisture lost by ET, rather than underestimating the LR fraction of total irrigation needed.

Also, understand that many of the scientific principles outlined in this text were first researched and developed for agricultural crop production situations, where daily equipment and pedestrian traffic, as well as maintaining a playing surface, can be controlled or are not of concern! Therefore, golfers need to understand that in implementing a salinity control program, playing conditions will need to be compromised from time to time.

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GENERATING RESULTS

The Audubon Cooperative Sanctuary Program for Golf Courses is helping superintendents to become stewards of the environment.

by JEAN MACKAY

IN 1991, Audubon International, in conjunction with the United States Golf Association, launched the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP). This environmental education program was designed to help golf courses play a significant role in enhancing and protecting wildlife habitat and natural resources. The ACSP provides an advisory information service to help golf courses conduct environmental projects and achieve positive recognition for their efforts.

Today, 2,140 courses throughout the United States are enrolled in the program, and 219 have achieved designation as *Certified Audubon Cooperative Sanctuaries* by implementing and documenting a full complement of conservation activities.

What is the result of participation in the ACSP? Do courses that participate achieve the program's desired goal of enhancing and protecting the environment?

To answer these questions, Audubon International conducted an environmental survey to assess the impact of program participation on a number of key environmental priority areas. These included: wildlife habitat conservation, water quality, and chemical use and reduction. In addition, the survey included a brief assessment of participant attitudes related to the impact of ACSP participation on golf playing quality, job satisfaction, and golfer satisfaction.

The survey was mailed in April 2000 to 2,035 ACSP golf course members. By the closing date in early July, 284 returns had been received, yielding a 14% response rate.

Results of the survey show strong environmental outcomes for participating courses: ACSP members significantly improved their environmental management practices while not sacrificing playing quality or golfer satisfaction.

"As we move into our tenth year of the program, we wanted to obtain more than qualitative information about the results of program participation," stated Larry Woolbright, Ph.D., Audubon International's Director of Research, who spearheaded the survey. "Information obtained from the survey is significant for *quantifying* results with hard numbers and statistics about how members have improved on a variety of environmental measures."

For example, since joining the program, members reported that, on average, acres devoted to providing wildlife habitat jumped from 40 to 70 acres per course — a 75% increase. In addition, 79% of ACSP members decreased the amount of managed turfgrass, and 64% are now monitoring wildlife activity — compared with just 16% before joining the program.

Helping members to reduce the use of pesticides and fertilizers as well as safely use, store, and handle chemicals is another key environmental priority of the ACSP. Results of the survey show that golf courses have been able to achieve that goal without sacrificing golf course playing quality. In fact, 86% reduced pesticide use and 92% reported using pesticides with a lower toxicity level since joining the program. About 84% increased the percentage of slow-release fertilizers used.

Best of all, ACSP members achieved these results without sacrificing playing quality. Both playing quality and golfer satisfaction remained the same or improved for 99% of ACSP golf courses. Sixty-four percent of ACSP participants also reported that job satisfaction improved as a result of joining the program.

The information compiled from the survey will be catalogued in Audubon International's Managed Lands Database, a database of wildlife habitats and environmental management practices on various types of properties. Results of the survey help to confirm that the program generates tangible environmental benefits in terms of increased wildlife habitats, decreased chemical use, and improved management practices.

"We applaud the courses who responded to the survey and who participate in the program," commented Ronald Dodson, Audubon International's President and CEO. "Not only are they contributing to improved environmental quality on golf courses, they are helping to spread the word that golf course superintendents can be excellent stewards of the environment."

JEAN MACKAY *serves as the manager of educational services for Audubon International. She has worked with golf course superintendents and other industry professionals since 1992 to promote environmental management practices and enhance the open space value of golf courses.*

For more information about the Audubon Cooperative Sanctuary Program for Golf Courses, contact:

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NEWS NOTES

USGA Turfgrass & Environmental Research

THE USGA Turfgrass and Environmental Research Committee met in Washington, D.C., to complete the selection of new research projects for 2001. Fifteen new projects were selected with a three-year funding commitment of $934,241. Of the new projects selected, three deal with putting green construction, four focus on the environmental impact of golf courses, and eight will investigate new integrated turfgrass management techniques (see table below). There were no new turfgrass breeding or molecular genetics projects selected. Two or three new Wildlife Links projects will be selected later this fall.

The announcement of the new research funding brings the USGA's commitment for 1998 through 2002 to more than $8 million for the five-year period. Included in this funding amount are other popular USGA programs such as Wildlife Links, the Audubon Cooperative Sanctuary Program, and the Turfgrass Information Center endowment. The 2001 proposal selection will be the last group of new projects for this five-year cycle. A new call for proposals for the next five-year funding cycle, beginning in 2003, will be made in late 2001 or early 2002. The Turfgrass and Environmental Research Committee will begin a thorough evaluation of the current projects and begin the process of assessing the future direction of the research program.

From 1983 through 2002, the USGA has funded more than 215 projects at a cost of $21 million. This private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. More than 80 graduate students have benefited from USGA funding, most receiving a Master of Science degree. More than 20 new turfgrass varieties with improved water use or stress resistance were produced. Six reference books and hundreds of articles have been published, especially during the last ten years of the research program. The USGA remains the nation's leading authority on golf course management and construction and will continue in this role for years to come.

New research projects receiving funding through the USGA Turfgrass and Environmental Research Program for 2001-2003*

Research Project	Institution		Research Grant
Course Construction			
Simulation of Putting Green Hydrology	Ohio State University/OARDC		$ 28,850
Long-Term Assessment of Putting Green Rootzone Mixes Under Two Microenvironments	Rutgers University		90,000
Soil Physical Characterization of Aging Golf Greens	University of Nebraska		81,375
		Subtotal	200,225
Environmental Impact			
Best Management Practices to Reduce Pesticide Runoff from Turf	University of Illinois		59,633
Fate of Pesticides and Their Partitioning Among Water, Soil, and Biomass Elements in a Turfgrass Ecosystem	Kansas State University		90,000
Operational Comprehensive Fate and Transport Model for Turfgrass Pesticides	Cornell University		48,952
Modeling Nitrogen and Phosphorus Runoff and Leaching from Golf Courses Using PRZM3/EXAMS2	University of Georgia		90,000
		Subtotal	288,585
Integrated Turfgrass Management			
Evaluation of Golf Turf Management Systems with Reduced Chemical Pesticide Inputs	Cornell University		87,000
Identification of Mechanisms of Resistance in Kentucky Bluegrass for Control of Black Cutworm in Turfgrass	University of Wisconsin		72,740
Three Biocontrol Agents for Pest Mole Crickets in Georgia	University of Florida		24,070
Determination of Critical Thresholds of Soil Temperature and Heat Accumulation Capacity Controlling Summer Bentgrass Decline for Various Creeping Bentgrasses	Kansas State University		89,985
Growth and Pathogenicity of *Ophiosphaerella agrostis* and Epidemiology of Bentgrass Dead Spot, a New Pathogen and Disease of Creeping Bentgrass	University of Maryland		27,000
Management of New Dwarf Bermudagrasses	Texas A&M University		21,156
Evaluation of Ultradwarf Bermudagrass Cultural Management Practices	University of Florida		32,480
On-Site Evaluation of Golf Course Products: Wetting Agents	GCSAA		100,000
		Subtotal	454,431
		Total	$943,241

*Total research grant to be divided over the three-year funding cycle.

Physical Soil Testing Laboratories*

The following laboratories are accredited by the American Association for Laboratory Accreditation (A2LA), having demonstrated ongoing competency in testing materials specified in the USGA's Recommendations for Putting Green Construction. The USGA recommends that only A2LA-accredited laboratories be used for testing and analyzing materials for building greens according to our guidelines.

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EUROPEAN TURFGRASS LABORATORIES LIMITED
Unit 58, Stirling Enterprise Park
Stirling FK7 7RP Scotland
Attn: John Souter
(44) 1786-449195 • (44) 1786-449688 FAX

N. W. HUMMEL & CO.
35 King Street, P.O. Box 606
Trumansburg, NY 14886
Attn: Norm Hummel
(607) 387-5694 • (607) 387-9499 FAX

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Olathe, KS 66061
Attn: Bob Oppold
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(913) 829-4013 FAX
e-mail: istrcNewMixLab@worldnet.att.net

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Attn: Michael S. Hindahl, Ph.D.
(503) 630-7769

THOMAS TURF SERVICES, INC.
1501 FM 2818, Suite 302
College Station, TX 77840-5247
Attn: Bob Yzaguirre / Jim Thomas
(409) 764-2050 • (409) 764-2152 FAX

TIFTON PHYSICAL SOIL TESTING LABORATORY, INC.
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Attn: Powell Gaines
(912) 382-7292 • (912) 382-7992 FAX

TURF DIAGNOSTICS AND DESIGN, INC.
310-A North Winchester Street
Olathe, KS 66062
Attn: Sam Ferro
(913) 780-6725 • (913) 780-6759 FAX

*Revised November 2000. Please contact the USGA Green Section (908-234-2300) for an updated list of accredited laboratories.

Two Welcome Additions to the Green Section Staff — Jeff Nus and Todd Lowe

From left: Jeff Nus and Todd Lowe.

TO MEET THE NEEDS of the ever-growing number of golf courses in Florida, Todd Lowe recently was hired as an agronomist for the Florida region.

Todd is a graduate of the University of Florida, where he majored in environmental horticulture, and he received a master's degree in horticulture from Clemson University in 1998, working with Dr. Bert McCarty. His master's degree studies focused on turfgrass weed control.

Todd gained his first real turfgrass experience at the age of 14, when he worked with his father, then a golf course superintendent in Florida. In 1999, Todd was selected as one of 15 students from across the country to participate in the USGA Green Section Internship Program, during which he spent a week making Turf Advisory Service visits with Green Section agronomists. Most recently, Todd worked at the Old Collier Golf Course in Naples, Florida. Old Collier currently is under construction and is being planted entirely to seashore paspalum.

Todd will be located on Florida's West Coast and will make Turf Advisory Service visits to the golf courses in that area. He will work with John Foy, director of the Florida Region.

Dr. Jeff Nus has joined the USGA Green Section staff in the newly created position of manager, Green Section Research. In this capacity, Jeff will create educational materials that summarize the results of the USGA's Turfgrass and Environmental Research Program. The information will be disseminated through the *Green Section Record*, the USGA website, and other communications media.

Most recently, Jeff served as director of research for the Golf Course Superintendents Association of America. Prior to his 10-year stint at GCSAA, Nus spent six years as an assistant professor at Kansas State University in Manhattan, Kansas. Currently he is the chairman of the Crop Science Society of America's Turfgrass Division. Jeff earned his bachelor's, master's, and doctoral degrees in horticulture, specializing in turfgrass management, from Iowa State University.

Jeff will base his office in Lawrence, Kansas, and report to Dr. Mike Kenna, director, Green Section Research.

The USGA Green Section staff welcomes both Todd and Jeff to the staff, and wishes them much success.

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I certify that the statements made by me above are correct and complete.

JAMES T. SNOW, Editor

Don't Make Promises You Should Not Keep!

Establishing realistic timelines for project completion can be crucial for long-term success.

by DARIN S. BEVARD

CONSIDER THIS: a new golf course is under construction; fairway grass conversion is scheduled for the fall; putting green renovation will begin in July. All are very important projects with one thing in common — the need for a deadline for opening or reopening.

In traveling the Mid-Atlantic Region of the USGA Green Section, I have had the opportunity to work with many different construction projects. I am amazed how often the timeline provided for opening or reopening is not only unrealistic, but offers a true opportunity to jeopardize the success of a major investment in the facility in the interest of gaining a small amount of additional playing time or revenue. Playability may be poor and the turfgrass is not ready to receive traffic, yet getting people out on the golf course is the priority, regardless of turf performance. Moreover, many times the opening date is established by someone with no working knowledge of turfgrass management! The decision is often arbitrary, without consideration for the potential condition of the turf at the time of opening.

When setting a timeline for opening a golf course after renovation or construction, there are several important issues to keep in mind to determine whether or not the promised opening date is in the best long-term interest of the golf course.

As the opening date approaches, the appearance of the grass on the surface can betray the true maturity of the turf, especially on putting greens. A newly constructed putting green will look traffic-worthy on the surface before it can actually tolerate the rigors of everyday maintenance and golfer traffic. Root and thatch development must also be considered.

Should the course open May 1 or May 15? What difference can two weeks make? The answer is *plenty* — if growing days are counted instead of calendar days.

In the Mid-Atlantic Region, it seems that most projects are completed between the middle of September and early October. Assuming an October 15 germination date, that leaves maybe 30 days of reasonable growing weather prior to winter. In the spring, another 30 days of good weather from April 1 to May 1 can be expected. While some development certainly occurs over the winter months, it is often minimal, especially under harsh weather conditions. On May 1, the greens are approximately 60 growing days old. On May 15, the greens are roughly 75 growing days in age. That two weeks provides 25% more time for turf development. That time can be crucial for sod strength and thatch development. This layer of organic matter is what cushions the turf from traffic.

When a course opens following construction or renovation, traffic will be heavy. There is no such thing as a "soft opening." Excitement over a new layout or relief at being able to return to the course after a long closure brings players out in droves. Additionally, if any reciprocal agreements were made with other courses when the course was closed, those chips will be cashed in as well. Fine turf areas must be ready when they are opened.

So what if there is a little bit of turf damage? Turf loss on a collar here, some damage on the front edge of the green there. A little seed and topdressing and everything is just fine. Not exactly. First of all, gaining recovery on fine turfgrass under regular play and maintenance is difficult. Secondly, there are issues unrelated to turf. For private clubs, getting approval for renovations is often politically sensitive. When renovated areas are less than perfect, naysayers will label the project a failure. Approval for future improvements can become even more difficult to obtain. For public facilities, poor turf conditions can lead to rumors of dead greens and poor playing conditions. This negative publicity can do irreparable damage to a course's reputation, leading to a loss in revenue and prestige.

How do you set a deadline? Make sure the decision makers are well informed and qualified to do so. Talk to the golf course or construction superintendent in detail. After all, the golf course superintendent will shoulder the blame for declining turf and be left to pick up the pieces if damage occurs after an early opening. While it is good to have a projection for the length of closure, weather and other delays can impact the best-laid plans.

What is the bottom line? Do not determine exact dates until after renovations are complete and turf grow-in commences. This will provide a better opportunity to evaluate progress, allowing a realistic schedule to be developed. Everyone wants to reopen from renovations and construction as soon as possible. However, damage to the course's turf and reputation can occur after a premature opening. All things considered, don't make promises that you shouldn't keep! Maintain a flexible schedule in the short term to preserve quality and project success for the long term.

DARIN BEVARD *joined the USGA Green Section in 1996 as an agronomist in the Mid-Atlantic Region. He visits golf courses in Pennsylvania, Maryland, Delaware, and Virginia.*

Subscriptions $18 a year, Canada/Mexico $21 a year, and international $33 a year (air mail).

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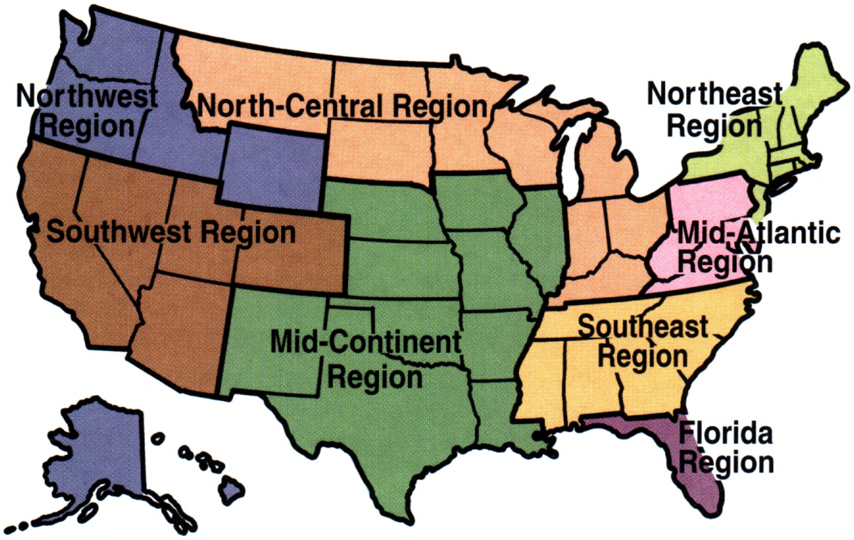

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TURF TWISTERS

INVEST

Question: We are about to upgrade our irrigation pumping station and I would like to include a flow meter so that monthly/annual waer use can be monitored. There has been resistance to funding a flow meter for our system. Is a flow meter a good investment? (Pennsylvania)

Answer: Absolutely. Installing a flow meter would be very proactive. In many states flow meters are required equipment. In fact, Pennsylvania is shifting to a metering basis to document water use. Annual reports must be submitted during a normal year, and monthly reports will be required during a drought emergency. During a drought emergency, water restrictions will be based on metered data. It's a case of "pay me now, or pay me later." You would be one step ahead if the meter is installed this season.

LONG TERM FOR

Question: We would like to restructure our Green Committee to provide long-term leadership, improving the continuity of our maintenance programs. Unfortunately, our club bylaws require that board members (who serve three-year maximum terms and rotate committee duties each season) chair each committee. Can you offer any suggestions? (Utah)

Answer: Consider appointing two individuals to "co-chair" the Green Committee. One person satisfies the bylaws as the board member liaison, and the other (not a board member) assumes the more active and longer-term role in the position, providing necessary continuity for ongoing programs. Also, when the time arrives for replacing the long-term, non-board position, consider a requirement that all candidates have a minimum of two years experience on the Green Committee. This will perpetuate the continuity of ongoing programs. For more tips on Green Committee organization, read the *USGA Green Committee Guide*, available for $2.00 through the USGA Order Department (800-336-4446).

LEVEL RETURNS

Question: We are preparing to rebuild some of our tees. Our plan is to use the same rootzone mixture that meets the USGA's guidelines for greens. We are going to put the mix down at a depth of six inches. Should we make the surface of the tee perfectly level, or is some slope necessary? (Arkansas)

Answer: Even though the mix you plan to use drains very well, we recommend you maintain some surface drainage (typically 0.5 to 1.0% slope). This will ensure the tee drains well even as the internal drainage of the rootzone decreases over the years. If possible, the tee should slope away from the entrance side of the tee to help reduce wet conditions in high-traffic areas.